employed trader over a two-decade-long career who did not live up to his handshake.

Only a sense of honor can lead to commerce. Any commerce.

Next

We saw how, thanks to the misunderstanding of antifragility (and asymmetry or convexity), some classes of people use hidden options and harm the collective without anyone realizing. We also saw the solution in forcing skin in the game. Next, we will look at another form of optionality: how people can cherry-pick ethical rules to fit their actions. Or how they use public office as a means to satisfy personal greed.

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[1] GSE is Fannie Mae and Freddie Mac—they both blew up.

[2] I find it truly disgusting that one of the Orszag brothers, Peter, after the crisis got a job with the Obama administration—another rehiring of blindfolded bus drivers. Then he became vice chairman of Citibank, which explains why Citibank will blow up again (and we taxpayers will end up subsidizing his high salary).

[3] My suggestion to deter "too big to fail" and prevent employers from taking advantage of the public is as follows. A company that is classified as potentially *bailable out* should it fail should not be able to pay anyone more than a corresponding civil servant. Otherwise people should be free to pay each other what they want since it does not affect the taxpayer. Such limitation would force companies to stay small enough that they would not be considered for a bailout in the event of their failure.

[4] I have had the same experience with journalists citing each other about my books without the smallest effort to go to my writings—my experience is that most journalists, professional academics, and other in similar phony professions don't read original sources, but each other, largely because they need to figure out the consensus before making a pronouncement.

[5] There seems to be a survival advantage to small or medium-sized owner-operated or family-owned companies.

CHAPTER 24

Fitting Ethics to a Profession

How the slaves can snatch control—Squeezing the sissies—The tantalized class, permanently tantalized

At no time in the history of mankind has the following situation been seen in such an acute form. Say Mr. John Smith Jr., JD, is employed as lobbyist for the tobacco industry in Washington, D.C., which, as we all know, is engaged in the business of killing people for profit (we saw with the powers of subtraction that if we stopped such industries from existing by, say, banning cigarettes, then everything else done by medicine becomes a footnote). Ask any of his relatives (or friends) why they can tolerate it and don't just ostracize him or harass him to tears, avoid him at the next family funeral. The answer is likely to be "everyone needs to make a living"—as they are hedging the possibility of their falling into the same situation some day.

We need to test the direction of the arrow (using the same logic as in our discussion of lecturing birds on flying):

Ethics (and Beliefs) → Profession

or

Profession → Ethics (and Beliefs)

Prior to Fat Tony's debate with Socrates, Nero was curious about the first minute of encounter, since there is a gap of about twenty-five centuries. It is not a simple matter to identify the elements of our physical environment that would surprise Socrates the most. Questioned on the point by Fat Tony, who had some

grudging respect for Nero's knowledge of history, Nero's speculative reply was "It would most certainly be the absence of slaves."

"These people never did small domestic things themselves. So imagine Socrates' sorry figure of a bulging belly, spindly legs, wondering *Opou oi douloi?*"

"But, Neeroh Toolip, there are still slaves around," Fat Tony blurted out. "They often distinguish themselves by wearing this intricate device called a necktie."

Nero: "Signore Ingeniere Tony, some of these tie-wearers are very rich, even richer than you."

Tony: "Nero, you sucker. Don't be fooled by money. These are just numbers. Being self-owned is a state of mind."

Wealth Without Independence

There is a phenomenon called the *treadmill effect,* similar to what we saw with neomania: you need to make more and more to stay in the same place. Greed is antifragile—though not its victims.

Back to the sucker problem in believing that wealth makes people more independent. We need no more evidence for it than what is taking place now: recall that we have never been richer in the history of mankind. And we have never been more in debt (for the ancients, someone in debt was not free, he was in bondage). So much for "economic growth."

At the local level, it looks like we get socialized in a certain milieu, hence exposed to a treadmill. You do better, move to Greenwich, Connecticut, then become a pauper next to a twenty-million-dollar mansion and million-dollar birthday parties. And you become more and more dependent on your job, particularly as your neighbors get big tax-sponsored Wall Street bonuses.

This class of persons is like Tantalus, who was subjected to an eternal punishment: he stood in a pool of water underneath a fruit tree and whenever he tried to grab the fruit it moved away and whenever he tried to drink, the water receded.

And such a permanently tantalized class is a modern condition. The Romans circumvented these social treadmill effects: much of social life took place between a patron and his less fortunate clients who benefited from his largesse and ate at his table—and relied on his assistance in times of trouble. There was no welfare at the time, and no church to distribute or recommend charity:

everything was private (Seneca's book *De beneficiis* I mentioned earlier was exactly about which obligations one had in such situations). There was little exposure to the other wealthy biggies, just as mafia dons don't socialize with other mafia dons but with their constituents. To a large extent, that's how my grandfather and great-grandfather lived, as they were local landowners and politicians; power was accompanied by a coterie of dependents. Provincial landowners were required to maintain an occasional "open house," with an open table for people to come help themselves to the fruits of the wealth. Court life, on the other hand, leads to corruption—the nobleman comes from the provinces, where he is now brought down to size; he faces more flamboyant, wittier persons and feels pressure to prop up his self-esteem. People who would have lost their status in the cities conserve it in the provinces.

You cannot possibly trust someone on a treadmill.

THE PROFESSIONALS AND THE COLLECTIVE

It is a fact that one can rapidly, after a phase of indoctrination, become enslaved to a profession, to the point of having one's opinions on any subject become self-serving, hence unreliable for the collective. This is the bone the Greeks had to pick with professionals.

One of my first jobs was for a Wall Street firm. After I'd been employed for a few months, the managing director called us up and told us that we needed to contribute to a few politicians' campaigns, with a "recommended" payment of a certain proportion of our income. These politicians were said to be "good." By "good" was meant good for their business of investment banking, as these politicians would help with legislation that would protect their business. Had I done that, I would no longer have been eligible ethically to voice a political opinion "for the sake of the public."

In a story well argued throughout the centuries, Demades the Athenian condemned a man who traded in funeral goods on the grounds that he could only derive profits by the death of the great many people. Montaigne, rephrasing the argument made by Seneca in his *De beneficiis*, argued that we would then be obligated to condemn every single professional. According to him, the merchant only thrives by the debauchery of youth, the farmer by the dearness of grain, the architect by the ruin of buildings, lawyers and officers of justice by the suits and contentions of men. A physician takes no pleasure in the health of even his friends, a soldier does not wish for the peace of his country, *etc.* And, even worse, should we go into people's inner and private thoughts and motivations, we would see that their wishes and hopes are almost invariably at someone else's expense.

But Montaigne and Seneca were a bit too indulgent toward self-interest and missed something quite central. They clearly got the point that economic life does not necessarily depend on altruistic motives, and that the aggregate works differently from the individual. Remarkably, Seneca was born about eighteen centuries before Adam Smith, and Montaigne about three, so we should be quite impressed with their thinking while retaining a certain abhorrence of the fundamental dishonesty of men. We have known since Adam Smith that the collective does not require the benevolence of individuals, as self-interest can be the driver of growth. But all this does not make people less unreliable *in their personal opinions* about the collective. For they are involving the skin of others,

so to speak.

What Montaigne and Seneca missed, in addition to the notion of skin in the game, was that one can draw the line with public affairs. They missed the agency problem—although the problem was known heuristically (Hammurabi, golden rules), it was not part of their consciousness.

The point isn't that making a living in a profession is inherently bad; rather, it's that such a person becomes automatically suspect when dealing with public affairs, matters that involve others. The definition of the *free man,* according to Aristotle, is one who is free with his opinions—as a side effect of being free with his time.

Freedom in this sense is only a matter of sincerity in political opinions.

The Greeks saw the world in three professions. The *banausikai technai*, the artisans; the craft of war, *polemike techne;* and that of farming, *georgia*. The last two professions, war and farming, were worthy of a gentleman—mainly because they were not self-serving and were free of conflicts of interest with the collective. But the Athenians despised the *banausoi*, the artisans who worked for a living in dark rooms making objects—generally sitting down. For Xenophon, such crafts degraded the craftsmen's bodily strength, softened his spirit, and left him no time for his friends and city. The illiberal arts confine one to the workshop and narrow one's interests *to his own welfare;* the crafts of war and farming give one a wider scope so that he can attend to his friends and city. To Xenophon, farming is the mother and nurse of the other *technai*. (The ancients did not have corporations; if Xenophon were alive today he would transfer his distrust from artisans to corporate employees.)

There are Arabic and Hebrew sayings, *Yad el hurr mizan / Yad ben horin moznayim*—"the hand of the free is a scale." It is just that the definition of the free is not well understood: he is free who owns his own opinion.

For Metternich, humanity started at the rank of baron; for Aristotle, as well as, though in a separate form, the English up until the twentieth century, it started at the rank of idle freeman, unpreoccupied with work. It never meant *not* working; it just meant not deriving your personal and emotional identity from your work, and viewing work as something optional, more like a hobby. In a way your profession does not identify you so much as other attributes, here your birth (but it could be something else). This is the *f*** you money* that allowed Thales of Miletus to gauge his own sincerity. For the Spartans, it was all about courage. For Fat Tony, humanity started at the level of "self-ownership."

Now self-ownership for our horizontal friend was vastly more democratic than for his thinking predecessors. It simply meant being the owner of your opinion. And it has nothing to do with wealth, birth, intelligence, looks, shoe size, rather with personal courage.

In other words, for Fat Tony, it was a very, very specific definition of a free person: someone who cannot be squeezed into doing something he would otherwise never do.

Consider this leap in sophistication from Athens to Brooklyn: if for the Greeks, only he who is free with his time is free with his opinion, for our horizontal friend and advisor, only he who has courage is free with his opinion. *Sissies are born, not made. They stay sissies no matter how much independence you give them, no matter how rich they get.*

Another facet of the difference between abstract modernistic nation-states and local government. In an antique city-state, or a modern municipality, shame is the penalty for the violation of ethics—making things more symmetric. Banishment and exile, or, worse, ostracism were severe penalties—people did not move around voluntarily and considered up-rooting a horrible calamity. In larger organisms like the mega holy nation-state, with a smaller role for face-to-face encounters, and social roots, shame ceases to fulfill its duty of disciplinarian. We need to reestablish it.

And aside from shame, there is friendship, socialization in a certain milieu, being part of a group of people that have diverging interests from the collective. Cleon, the hero of the Peloponnesian War, advocated the public renouncement of friends upon taking up public affairs—he paid for it with some revilement by historians.

A simple solution, but quite drastic: anyone who goes into public service should not be allowed to *subsequently* earn more from any commercial activity than the income of the highest paid civil servant. It is like a voluntary cap (it would prevent people from using public office as a credential-building temporary accommodation, then going to Wall Street to earn several million dollars). This would get priestly people into office.

Just as Cleon was reviled, in the modern world, there seems to be an inverse agency problem for those who do the right thing: you pay for your service to the public with smear campaigns and harassment. The activist and advocate Ralph Nader suffered numerous smear campaigns as the auto industry went after him.

THE ETHICAL AND THE LEGAL

I felt ashamed not having exposed the following scam for a long time. (As I said, *if you see fraud* …) Let us call it the Alan Blinder problem.

The story is as follows. At Davos, during a private coffee conversation that I thought aimed at saving the world from, among other things, moral hazard and agency problems, I was interrupted by Alan Blinder, a former vice chairman of the Federal Reserve Bank of the United States, who tried to sell me a peculiar investment product that aims at legally hoodwinking taxpayers. It allowed the high net worth investor to get around the regulations limiting deposit insurance (at the time, $100,000) and benefit from coverage for near-unlimited amounts. The investor would deposit funds in any amount and Prof. Blinder's company would break it up into smaller accounts and invest in banks, thus escaping the limit; it would look like a single account but would be insured in full. In other words, it would allow the super-rich to scam taxpayers by getting free government-sponsored insurance. Yes, *scam* taxpayers. Legally. With the help of former civil servants who have an insider edge.

I blurted out: "Isn't this unethical?" I was then told in response "It is perfectly legal," adding the even more incriminating "we have plenty of former regulators on the staff," (a) implying that what was legal was ethical and (b) asserting that former regulators have an edge over citizens.

It took a long time, a couple of years, before I reacted to the event and did my public *J'accuse*. Alan Blinder is certainly not the worst violator of my sense of ethics; he probably irritated me because of the prominence of his previous public position, while the Davos conversation was meant to save the world from evil (I was presenting to him my idea of how bankers take risks at the expense of taxpayers). But what we have here is a model of how people use public office to, at some point, legally profit from the public.

Tell me if you understand the problem in its full simplicity: former regulators and public officials who were employed by the citizens to represent their best interests can use the expertise and contacts acquired on the job to benefit from glitches in the system upon joining private employment—law firms, *etc.*

Think about it a bit further: the more complex the regulation, the more bureaucratic the network, the more a regulator who knows the loops and glitches would benefit from it later, as his regulator edge would be a convex function of his differential knowledge. This is a franchise, an asymmetry one has at the

expense of others. (Note that this franchise is spread across the economy; the car company Toyota hired former U.S. regulators and used their "expertise" to handle investigations of its car defects.)

Now stage two—things get worse. Blinder and the dean of Columbia University Business School wrote an op-ed opposing the government's raising the insurance limit on individuals. The article argued that the public should not have the unlimited insurance that Blinder's clients benefit from.

A few remarks.

First, the more complicated the regulation, the more prone to arbitrages by insiders. This is another argument in favor of heuristics. Twenty-three hundred pages of regulation—something I can replace with Hammurabi's rule—will be a gold mine for former regulators. The incentive of a regulator is to have complex regulation. Again, the insiders are the enemies of the *less-is-more* rule.

Second, the difference between the letter and the spirit of regulation is harder to detect in a complex system. The point is technical, but complex environments with nonlinearities are easier to game than linear ones with a small number of variables. The same applies to the gap between the legal and the ethical.

Third, in African countries, government officials get explicit bribes. In the United States they have the implicit, never mentioned, promise to go work for a bank at a later date with a sinecure offering, say $5 million a year, if they are seen favorably by the industry. And the "regulations" of such activities are easily skirted.

What upset me the most about the Alan Blinder problem is the reactions by those with whom I discussed it: people found it natural that a former official would try to "make money" thanks to his former position—at our expense. *Don't people like to make money?* goes the argument.

Casuistry as Optionality

You can always find an argument or an ethical reason to defend an opinion ex post. This is a dicey point, but, as with cherry-picking, one should propose an ethical rule before an action, not after. You want to prevent fitting a narrative to what you are doing—and for a long time "casuistry," the art of arguing the nuances of decisions, was just that, fitting narratives.

Let me first define a fraudulent opinion. It is simply one with vested interests generalized to the public good—in which, say a hairdresser recommends haircuts "for the health of people," or a gun lobbyist claims gun ownership is

"good for America," simply making statements that benefit him personally, while the statements are dressed up to look as if they were made for the benefit of the collective. In other words, is he in the left column of Table 7? Likewise, Alan Blinder wrote that he opposed generalized deposit insurance, not because his company would lose business, but *because of the public good*.

But the heuristic is easy to implement, with a simple question. I was in Cyprus at a conference dinner in which another speaker, a Cypriot professor of petrochemical engineering in an American university, was ranting against the climate activist Lord Nicholas Stern. Stern was part of the conference but absent from the dinner. The Cypriot was extremely animated. I had no idea what the issues were, but saw the notion of "absence of evidence" mixed with "evidence of absence" and pounced on him in defense of Stern, whom I had never met. The petrochemical engineer was saying that we had *no evidence* that fossil fuels caused harm to the planet, turning his point semantically into something equivalent in decision making to the statement that that we had *evidence that fossil fuels did not harm*. He made the mistake of saying that Stern was recommending useless insurance, causing me to jump to ask him if he had car, health, and other insurance for events that did not take place, that sort of argument. I started bringing up the idea that we are doing something new to the planet, that the burden of evidence is on those who disturb natural systems, that Mother Nature knows more than he will ever know, not the other way around. But it was like talking to a defense lawyer—sophistry, and absence of convergence to truth.

Then a heuristic came to mind. I surreptitiously asked a host sitting next to me if the fellow had anything to gain from his argument: it turned out that he was deep into oil companies, as an advisor, an investor, and a consultant. I immediately lost interest in what he had to say and the energy to debate him in front of others—his words were nugatory, just babble.

Note how this fits into the idea of skin in the game. If someone has an opinion, like, say, the banking system is fragile and should collapse, I want him invested in it so he is harmed if the audience for his opinion are harmed—as a token that he is not an empty suit. But when general statements about the collective welfare are made, instead, *absence* of investment is what is required. *Via negativa*.

I have just presented the mechanism of ethical optionality by which *people fit their beliefs to actions rather than fit their actions to their beliefs*. Table 8 compares professions with respect to such ethical backfitting.

Click here for a larger image of this table.

TABLE 8 • COMPARING PROFESSIONS AND ACTIVITIES

INVITED TO BE OPPORTUNIST (FITS ETHICS TO PROFESSION)	*PROTECTED FROM PLAYING THE PSEUDOETHICS GAME*
Gold-digger	Prostitute
Networker	Social person
Compromises	Doesn't compromise
Someone "here to help"	Erudite, dilettante, amateur
Merchant, professional (Classical period)	Landowner (Classical period)
Employee	Artisan
Academic at a research university, researcher depending on "grants"	Lens maker, philosophy teacher in a college or Lycée high school, independent scholar

There exists an inverse Alan Blinder problem, called "evidence against one's interest." One should give more weight to witnesses and opinions when they present the opposite of a conflict of interest. A pharmacist or an executive of Big Pharma who advocates starvation and *via negativa* methods to cure diabetes would be more credible than another one who favors the ingestion of drugs.

BIG DATA AND THE RESEARCHER'S OPTION

This is a bit technical, so the reader can skip this section with no loss. But optionality is everywhere, and here is a place to discuss a version of cherry-picking that destroys the entire spirit of research and makes the abundance of data extremely harmful to knowledge. More data means more information, perhaps, but it also means more false information. We are discovering that fewer and fewer papers replicate—textbooks in, say, psychology need to be revised. As to economics, fuhgetaboudit. You can hardly trust many statistically oriented sciences—especially when the researcher is under pressure to publish for his career. Yet the claim will be "to advance knowledge."

Recall the notion of epiphenomenon as a distinction between real life and libraries. Someone looking at history from the vantage point of a library will necessarily find many more spurious relationships than one who sees matters in the making, in the usual sequences one observes in real life. He will be duped by more epiphenomena, one of which is the direct result of the excess of data as compared to real signals.

We discussed the rise of noise in Chapter 7. Here it becomes a worse problem, because there is an optionality on the part of the researcher, no different from that of a banker. The researcher gets the upside, truth gets the downside. The researcher's free option is in his ability to pick whatever statistics can confirm his belief—or show a good result—and ditch the rest. He has the *option* to stop once he has the right result. But beyond that, he can find statistical relationships —the spurious rises to the surface. There is a certain property of data: in large data sets, large deviations are vastly more attributable to noise (or variance) than to information (or signal).[1]

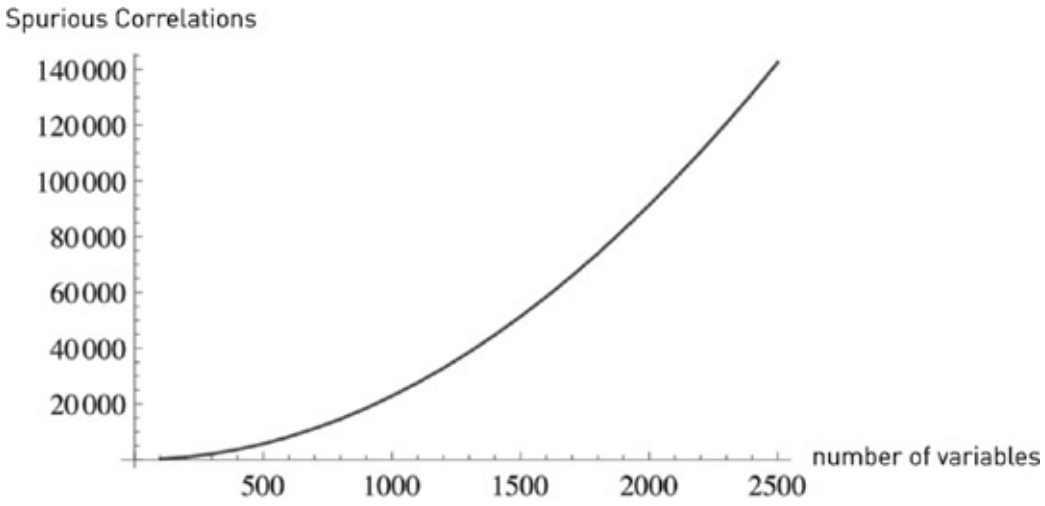

FIGURE 18. The Tragedy of Big Data. The more variables, the more correlations that can show significance in the hands of a "skilled" researcher. Falsity grows faster than information; it is nonlinear (convex) with respect to data.

There is a difference in medical research between (a) observational studies, in which the researcher looks at statistical relationships on his computer, and (b) the double-blind cohort experiments that extract information in a realistic way that mimics real life.

The former, that is, observation from a computer, produces all manner of results that tend to be, as last computed by John Ioannides, now more than eight times out of ten, spurious—yet these observational studies get reported in the papers and in *some* scientific journals. Thankfully, these observational studies are not accepted by the Food and Drug Administration, as the agency's scientists know better. The great Stan Young, an activist against spurious statistics, and I found a genetics-based study in *The New England Journal of Medicine* claiming significance from statistical data—while the results to us were no better than random. We wrote to the journal, to no avail.

Figure 18 shows the swelling number of potential spurious relationships. The idea is as follows. If I have a set of 200 random variables, completely unrelated to each other, then it would be near impossible not to find in it a high correlation of sorts, say 30 percent, but that is entirely spurious. There are techniques to control the cherry-picking (one of which is known as the Bonferoni adjustment), but even then they don't catch the culprits—much as regulation doesn't stop insiders from gaming the system. This explains why in the twelve years or so since we've decoded the human genome, not much of significance has been found. I am not saying that there is no information in the data: the problem is

that the needle comes in a haystack.

Even experiments can be marred with bias: the researcher has the incentive to select the experiment that corresponds to what he was looking for, hiding the failed attempts. He can also formulate a hypothesis after the results of the experiment—thus fitting the hypothesis to the experiment. The bias is smaller, though, than in the previous case.

The fooled-by-data effect is accelerating. There is a nasty phenomenon called "Big Data" in which researchers have brought cherry-picking to an industrial level. Modernity provides too many variables (but too little data per variable), and the spurious relationships grow much, much faster than real information, as noise is convex and information is concave.

Increasingly, data can only truly deliver *via negativa*–style knowledge—it can be effectively used to debunk, not confirm.

The tragedy is that it is very hard to get funding to replicate—and reject—existing studies. And even if there were money for it, it would be hard to find takers: trying to replicate studies will not make anyone a hero. So we are crippled with a distrust of empirical results, except for those that are negative. To return to my romantic idea of the amateur and tea-drinking English clergyman: the professional researcher competes to "find" relationships. Science must not be a competition; it must not have rankings—we can see how such a system will end up blowing up. Knowledge must not have an agency problem.

THE TYRANNY OF THE COLLECTIVE

Mistakes made collectively, not individually, are the hallmark of organized knowledge—and the best argument against it. The argument "because everyone is doing it" or "that's how others do it" abounds. It is not trivial: people who on their own would not do something because they find it silly now engage in the same thing but in groups. And this is where academia in its institutional structure tends to violate science.

One doctoral student at the University of Massachusetts, Chris S., once came to tell me that he believed in my ideas of "fat tails" and my skepticism of current methods of risk management, but that it would not help him get an academic job. "It's what everybody teaches and uses in papers," he said. Another student explained that he wanted a job at a good university so he could make money testifying as an expert witness—they would not buy my ideas on robust risk management because "everyone uses these textbooks." Likewise, I was asked by the administration of a university to teach standard risk methods that I believe are pure charlatanism (I refused). Is my duty as a professor to get students a job at the expense of society, or to fulfill my civic obligations? Well, if the former is the case, then economics and business schools have a severe ethical problem. For the point is generalized and that's why economics hasn't collapsed yet in spite of the obvious nonsense in it—and *scientifically proven* nonsense in it. (In my "fourth quadrant" paper—see discussion in the Appendix—I show how these methods are empirically invalid, in addition to being severely mathematically inconsistent, in other words, a scientific swindle). Recall that professors are not penalized when they teach you something that blows up the financial system, which perpetuates the fraud. Departments need to teach *something* so students get jobs, even if they are teaching snake oil—this got us trapped in a circular system in which everyone knows that the material is wrong but nobody is free enough or has enough courage to do anything about it.

The problem is that the last place on the planet where the "other people think so" argument can be used is science: science is precisely about arguments standing on their own legs, and something proven to be wrong empirically or mathematically is plain wrong, whether a hundred "experts" or three trillion disagree with the statement. And the very use of "other people" to back up one's claims is indicative that the person—or the entire collective that composes the "other"—is a wimp. The appendix shows what has been busted in economics,

and what people keep using because they are not harmed by error, and that's the optimal strategy for keeping a job or getting a promotion.

But the good news is that I am convinced that a single person with courage can bring down a collective composed of wimps.

And here, once again, we need to go back into history for the cure. The scriptures were quite aware of the problem of the diffusion of responsibility and made it a sin to follow the crowd in doing evil—as well as to give false testimony in order to conform to the multitude.

I close Book VII with a thought. Whenever I hear the phrase "I am ethical" uttered, I get tense. When I hear about classes in ethics, I get even more tense. All I want is to remove the optionality, reduce the antifragility of some at the expense of others. It is simple *via negativa*. The rest will take care of itself.

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[1] It is a property of sampling. In real life, if you are observing things in real time, then large deviations matter a lot. But when a researcher looks for them, then they are likely to be bogus—in real life there is no cherry-picking, but on the researcher's computer, there is.

CHAPTER 25

Conclusion

As usual at the end of the journey, while I was looking at the entire manuscript on a restaurant table, someone from a Semitic culture asked me to explain my book standing on one leg. This time it was Shaiy Pilpel, a probabilist with whom I've had a two-decades-long calm conversation without a single episode of small talk. It is hard to find people knowledgeable and confident enough to like to extract the essence of things, instead of nitpicking.

With the previous book, one of his compatriots asked me the same question, but I had to think about it. This time I did not even have to make an effort.

It was so obvious that Shaiy summed it up it himself in the same breath. He actually believes that all real ideas can be distilled down to a central issue that the great majority of people in a given field, by dint of specialization and empty-suitedness, completely miss. Everything in religious law comes down to the refinements, applications, and interpretations of the Golden Rule, "Don't do unto others what you don't want them to do to you." This we saw was the logic behind Hammurabi's rule. And the Golden Rule was a true distillation, not a Procrustean bed. A central argument is never a summary—it is more like a generator.

Shaiy's extraction was: *Everything gains or loses from volatility*. *Fragility is what loses from volatility and uncertainty*. The glass on the table is short volatility.

In the novel *The Plague* by Albert Camus, a character spends part of his life searching for the perfect opening sentence for a novel. Once he had that sentence, he had the full book as a derivation of the opening. But the reader, to understand and appreciate the first sentence, will have to read the entire book.

I glanced at the manuscript with a feeling of calm elation. Every sentence in the book was a derivation, an application, or an interpretation of the short maxim. Some details and extensions can be counterintuitive and elaborate, particularly when it comes to decision making under opacity, but at the end

everything flows from it.

The reader is invited to do the same. Look around you, at your life, at objects, at relationships, at entities. You may replace *volatility* with other members of the disorder cluster here and there for clarity, but it is not even necessary—when formally expressed, it is all the same symbol. Time is volatility. Education, in the sense of the formation of character, personality, and acquisition of true knowledge, likes disorder; label-driven education and educators abhor disorder. Some things break because of error, others don't. Some theories fall apart, not others. Innovation is precisely something that gains from uncertainty: and some people sit around waiting for uncertainty and using it as raw material, just like our ancestral hunters.

Prometheus is long disorder; Epimetheus is short disorder. We can separate people and the quality of their experiences based on exposure to disorder and appetite for it: Spartan hoplites contra bloggers, adventurers contra copy editors, Phoenician traders contra Latin grammarians, and pirates contra tango instructors.

It so happens that everything nonlinear is convex or concave, or both, depending on the intensity of the stressor. We saw the link between convexity and liking volatility. So everything likes or hates volatility up to a point. Everything.

We can detect what likes volatility thanks to convexity or acceleration and higher orders, since convexity is the response by a thing that likes disorder. We can build Black Swan–protected systems thanks to detection of concavity. We can take medical decisions by understanding the convexity of harm and the logic of Mother Nature's tinkering, on which side we face opacity, which error we should risk. Ethics is largely about stolen convexities and optionality.

More technically, we may never get to know x, but we can play with the exposure to x, barbell things to defang them; we can control a function of x, $f(x)$, even if x remains vastly beyond our understanding. We can keep changing $f(x)$ until we are comfortable with it by a mechanism called *convex transformation*, the fancier name for the barbell.

This short maxim also tells you where fragility supersedes truth, why we lie to children, and why we humans got a bit ahead of ourselves in this large enterprise called modernity.

Distributed randomness (as opposed to the concentrated type) is a necessity, not an option: everything big is short volatility. So is everything fast. Big and fast are abominations. Modern times don't like volatility.

And the Triad gives us some indication of what should be done to live in a world that does not want us to understand it, a world whose charm comes from our inability to truly understand it.

The glass is dead; living things are long volatility. The best way to verify that you are alive is by checking if you like variations. Remember that food would not have a taste if it weren't for hunger; results are meaningless without effort, joy without sadness, convictions without uncertainty, and an ethical life isn't so when stripped of personal risks.

And once again, reader, thank you for reading my book.

EPILOGUE

From Resurrection to Resurrection

It was an aortic aneurism.

Nero was in the Levant for his annual celebration of the death and rebirth of Adonis. It was a period of mourning with wailing women, followed by a celebration of resurrection. He watched nature waking up from the mild Mediterranean winter, when the rivers are full of reddish water, the blood of the Phoenician god wounded by the boar, as the melted snow from the mountains swelled the rivers and rivulets.

Things in nature move ahead from resurrection to resurrection.

That was when Tony's driver called. His name was also Tony, and while identified as Tony-the-driver he pretended he was a bodyguard (when in fact it looked like, given the comparative size, he was the one bodyguarded by Tony). Nero never liked him, always had that strange feeling of distrust, so the moment of sharing the news was odd. During his silence on the line, he felt sympathy for Tony-the-driver.

Nero was designated as the executor of Tony's will, which made him initially nervous. He had somehow a fear that Tony's wisdom would have a gigantic Achilles' heel somewhere. But, it turned out, there was nothing serious, a flawless estate, of course debt-free, conservative, fairly distributed. There were some funds to discreetly provide to a woman likely to be a prostitute, for whom Tony had some antifragile obsessive love, of course helped by the fact that she was both older and much less attractive than Tony's wife, that sort of thing. So nothing serious.

Except for the posthumous prank. Tony bequeathed to Nero a sum of twenty million dollars to spend at his discretion on … It was to be a secret mission; noble of course, but secret. And, of course, vague. And dangerous. It was the best compliment Nero ever got from Tony: trusting that Nero would be able to read his mind.

Which he did.

GLOSSARY

Triad: The triplet Antifragility, Robustness, Fragility.

Fundamental Asymmetry (also **Seneca's Asymmetry**): When someone has *more upside than downside* in a certain situation, he is antifragile and tends to gain from (a) volatility, (b) randomness, (c) errors, (d) uncertainty, (e) stressors, (f) time. And the reverse.

Procrustean bed: Procrustes got people to fit perfectly into his bed by cutting or stretching their limbs. Corresponds to situations in which simplifications are not simplifications.

Fragilista: Someone who causes fragility because he thinks he understands what's going on. Also usually lacks sense of humor. See **Iatrogenics.** Often Fragilistas fragilize by depriving variability-loving systems of variability and error-loving systems of errors. They tend to mistake organisms for machines and engineering projects.

Lecturing-Birds-How-to-Fly Effect: Inverting the arrow of knowledge to read academia → practice, or education → wealth, to make it look as though technology owes more to institutional science than it actually does.

Touristification: The attempt to suck randomness out of life. Applies to soccer moms, Washington civil servants, strategic planners, social engineers, "nudge" manipulators, *etc.* Opposite: **rational flâneur.**

Rational flâneur (or just **flâneur**): Someone who, unlike a tourist, makes a decision opportunistically at every step to revise his schedule (or his destination) so he can imbibe things based on new information obtained. In research and entrepreneurship, being a flâneur is called "looking for optionality." A non-narrative approach to life.

Barbell Strategy: A dual strategy, a combination of two extremes, one safe and

one speculative, deemed more robust than a "monomodal" strategy; often a necessary condition for antifragility. For instance, in biological systems, the equivalent of marrying an accountant and having an occasional fling with a rock star; for a writer, getting a stable sinecure and writing without the pressures of the market during spare time. Even trial and error are a form of barbell.

Iatrogenics: Harm done by the healer, as when the doctor's interventions do more harm than good.

Generalized Iatrogenics: By extension, applies to the harmful side effects of actions by policy makers and activities of academics.

Tantalized Class: An economic condition of making more than minimum wage *and* wishing for more wealth. Workers, monks, hippies, some artists, and English aristocrats escape it. The middle class tends to fall into it; so do Russian billionaires, lobbyists, most bankers, and bureaucrats. Members are bribable provided they are given an adequate narrative, mostly with the use of casuistry.

Black Swan Errors

> **Nonpredictive Approach**: Building stuff in a manner immune to perturbations—hence robust to changes in future outcomes.
>
> **Thalesian versus Aristotelian**: The Thalesian focuses on exposure, payoff from decision; the Aristotelian focuses on logic, the True-False distinction. For Fat Tony, the problem is all about sucker-nonsucker, or risks and rewards. (Also see **nonlinearities**, **convexity effects**.)
>
> **Conflation of Event and Exposure**: Mistaking a function of a variable for the variable itself.

Naturalistic Risk Management: The belief that, when it comes to risk management, Mother Nature has a much, much more significant track record than rationalistic humans. It is imperfect, but much better.

Burden of evidence: The burden of evidence falls on those who disrupt the natural, or those who propose *via positiva* policies.

Ludic Fallacy: Mistaking the well-posed problems of mathematics and

laboratory experiments for the ecologically complex real world. Includes mistaking the randomness in casinos for that in real life.

Antifragile Tinkering, Bricolage: A certain class of trial and error, with small errors being "the right" kind of mistakes. All equivalent to **rational flâneur.**

Hormesis: A bit of a harmful substance, or stressor, in the right dose or with the right intensity, stimulates the organism and makes it better, stronger, healthier, and prepared for a stronger dose the next exposure. (Think of bones and karate.)

Naive Interventionism: Intervention with disregard to **iatrogenics.** The preference, even obligation, to "do something" over doing nothing. While this instinct can be beneficial in emergency rooms or ancestral environments, it hurts in others in which there is an "expert problem."

Naive Rationalism: Thinking that the reasons for things are, by default, accessible to university buildings. Also called the **Soviet-Harvard illusion.**

Turkey and Inverse Turkey: The turkey is fed by the butcher for a thousand days, and every day the turkey pronounces with increased statistical confidence that the butcher "will never hurt it"—until Thanksgiving, which brings a Black Swan revision of belief for the turkey. The **inverse turkey** error is the mirror confusion, not seeing opportunities—pronouncing that one has evidence that someone digging for gold or searching for cures will "never find" anything.

Doxastic Commitment, or **"Soul in the Game"**: You must only believe predictions and opinions by those who committed themselves to a certain belief, and had something to lose, in a way to pay a cost in being wrong.

Heuristics: Simple, practical, easy-to-apply rules of thumb that make life easy. These are necessary (we do not have the mental power to absorb all information and tend to be confused by details) but they can get us in trouble as we do not know we are using them when forming judgments.

Opaque Heuristic: Routine performed by societies that does not seem to make sense yet has been done for a long time and sticks for unknown reasons.

Dionysian: Opaque heuristic seemingly irrational, named after Dionysos (or Bacchus for Romans), the god of wine and revelling. Is contrasted to the

Apollonian, which represents order.

Agency Problem: Situation in which the manager of a business is not the true owner, so he follows a strategy that cosmetically seems to be sound, but in a hidden way benefits him and makes him antifragile at the expense (fragility) of the true owners or society. When he is right, he collects large benefits; when he is wrong, others pay the price. Typically this problem leads to fragility, as it is easy to hide risks. It also affects politicians and academics. A major source of fragility.

Hammurabi Risk Management: The idea that a builder has more knowledge than the inspector and can hide risks in the foundations where they can be most invisible; the remedy is to remove the incentive in favor of delayed risk.

Green Lumber Fallacy: Mistaking the source of important or even necessary knowledge—the greenness of lumber—for another, less visible from the outside, less tractable one. How theoreticians impute wrong weights to what one should know in a certain business or, more generally, how many things we call "relevant knowledge" aren't so much so.

Skin in the Game / Captain and Ship Rule: Every captain goes down with every ship. This removes the **agency problem** and the lack of **doxastic commitment.**

Empedocles' Tile: A dog sleeps on the same tile because of a natural, biological, explainable or nonexplainable match, confirmed by long series of recurrent frequentation. We may never know the reason, but the match is there. Example: why we read books.

Cherry-picking: Selecting from the data what serves to prove one's point and ignoring disconfirming elements.

Ethical Problems as Transfers of Asymmetry (fragility): Someone steals antifragility and optionality from others, getting the upside and sticking others with the downside. "Others' skin in the game."

> **The Robert Rubin violation**: Stolen optionality. Getting upside from a strategy without downside for oneself, leaving the harm to society. Rubin got

$120 million in compensation from Citibank; taxpayers are retrospectively paying for his errors.

The Alan Blinder problem: (1) Using privileges of office retrospectively at the expense of citizens. (2) Violating moral rules while complying perfectly with the law; confusion of ethical and legal. (3) The regulator's incentive to make complicated regulations in order to subsequently sell his "expertise" to the private sector.

The Joseph Stiglitz problem: Lack of penalty from bad recommendation causing harm to others. Mental **cherry-picking,** leading to contributing to the cause of a crisis while being convinced of the opposite—and thinking he predicted it. Applies to people with opinions without skin in the game.

Rational Optionality: Not being locked into a given program, so one can change his mind as he goes along based on discovery or new information. Also applies to **rational flâneur.**

Ethical Inversion: Fitting one's ethics to actions (or profession) rather than the reverse.

Narrative Fallacy: Our need to fit a story, or pattern, to a series of connected or disconnected facts. The statistical application is data mining.

Narrative Discipline: Discipline that consists of fitting a convincing and good-sounding story to the past. Opposed to experimental discipline. A great way to fool people is to use statistics as part of the narrative, by ferreting out "good stories" from the data thanks to cherry picking; in medicine, epidemiological studies tend to be marred with the narrative fallacy, less so controlled experiments. Controlled experiments are more rigorous, less subjected to **cherry-picking.**

Non-narrative action: Does not depend on a narrative for the action to be right —the narrative is just there to motivate, entertain, or prompt action. See **flâneur.**

Robust Narrative: When the narrative does not produce opposite conclusions or recommendations for action under change of assumption or environment. The narrative is otherwise fragile. Similarly, a robust model or mathematical tool

does not lead to different policies when you change some parts of the model.

Subtractive Knowledge: You know what is wrong with more certainty than you know anything else. An application of ***via negativa.***

Via negativa: In theology and philosophy, the focus on what something is not, an indirect definition. In action, it is a recipe for what to avoid, what not to do—subtraction, not addition, say, in medicine.

Subtractive Prophecy: Predicting the future by removing what is fragile from it rather than naively adding to it. An application of ***via negativa.***

Lindy Effect: A technology, or anything nonperishable, increases in life expectancy with every day of its life—unlike perishable items (such as humans, cats, dogs, and tomatoes). So a book that has been a hundred years in print is likely to stay in print another hundred years.

Neomania: A love of change for its own sake, a form of philistinism that does not comply with the **Lindy effect** and understands fragility. Forecasts the future by adding, not subtracting.

Opacity: You do not see the barrel when someone is playing Russian roulette. More generally, some things remain opaque to us, leading to illusions of understanding.

Mediocristan: A process dominated by the mediocre, with few extreme successes or failures (say, income for a dentist). No single observation can meaningfully affect the aggregate. Also called “thin-tailed,” or member of the Gaussian family of distributions.

Extremistan: A process where the total can be conceivably impacted by a single observation (say, income for a writer). Also called “fat-tailed.” Includes the fractal, or power-law, family of distributions.

Nonlinearities, Convexity Effects (smiles and frowns): Nonlinearities can be concave or convex, or a mix of both. The term **convexity effects** is an extension and generalization of the fundamental asymmetry. The technical name for fragility is negative convexity effects and for antifragility is positive convexity effects. Convex is good (a smiley), concave is bad (a frowny).

Philosopher's Stone, also called **Convexity Bias** (very technical): The exact measure of benefits derived from nonlinearity or optionality (or, even more technically, the difference between x and a convex function of x). For instance, such bias can quantify the health benefits of variable intensity of pulmonary ventilation over steady pressure, or compute the gains from infrequent feeding. The **Procrustean bed** from the neglect of nonlinearity (to "simplify") lies in assuming such convexity bias does not exist.

Appendix I:

A GRAPHICAL TOUR OF THE BOOK

For those nonliterary folks who like to see things in graphs, rather than words, and those only.

NONLINEARITY AND LESS IS MORE (& PROCRUSTEAN BED)

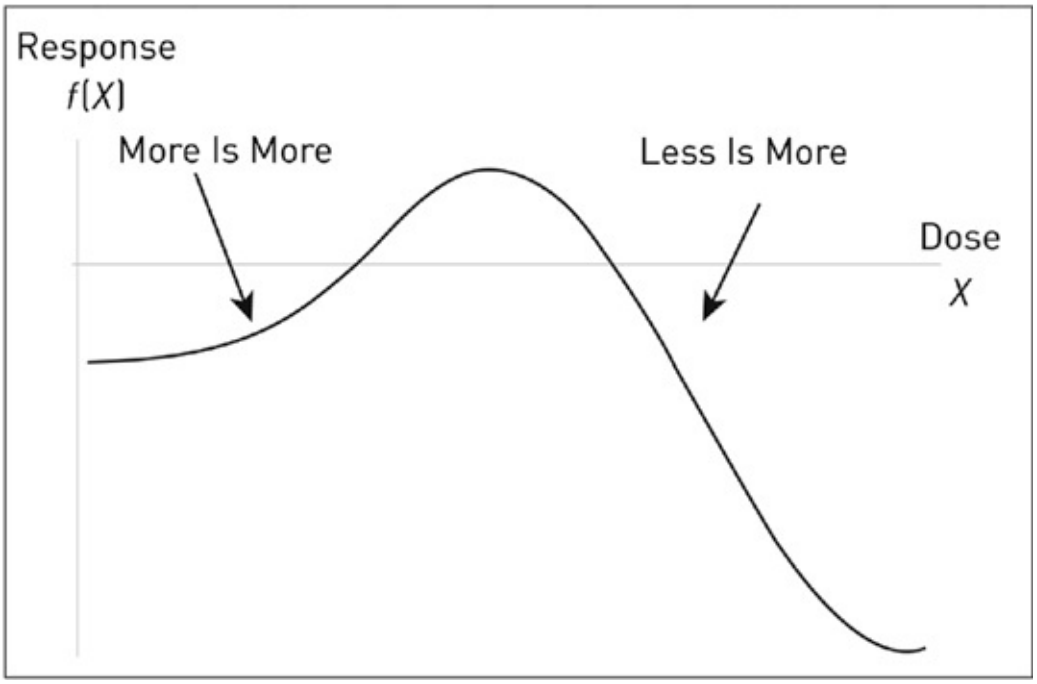


FIGURE 19. *This graph explains both the nonlinear response and the "less is more" idea. As the dose increases beyond a certain point, benefits reverse. We saw that everything nonlinear is either convex, concave, or, as in this graph, mixed. Also shows how under nonlinearities, reductions fail: the Procrustean bed of words "good for you" or "bad" is severely distorting.*

Also shows why tinkering-derived heuristics matter because they don't take you into the danger zone—words and narratives do. Note how the "more is more" zone is convex, meaning accelerated initial benefits. (In Levantine Arabic, the zone beyond the saturation has a name: كترتا مثل قلتا *"more of it is like less of it.")*

Finally, it shows why competitive "sophistication" (rather, complication masked as sophistication) is harmful, as compared to the practitioner's craving for optimal simplicity.

Fragility Transfer Theorem:

Note that by the Fragility Transfer Theorem,

CONVEX EXPOSURE [OVER SOME RANGE] ↔ LIKES VOLATILITY [UP TO SOME POINT]

(volatility and other members of the disorder cluster), and

CONCAVE EXPOSURE ↔ DISLIKES VOLATILITY

MAPPING OF FRAGILITIES

In Time Series Space

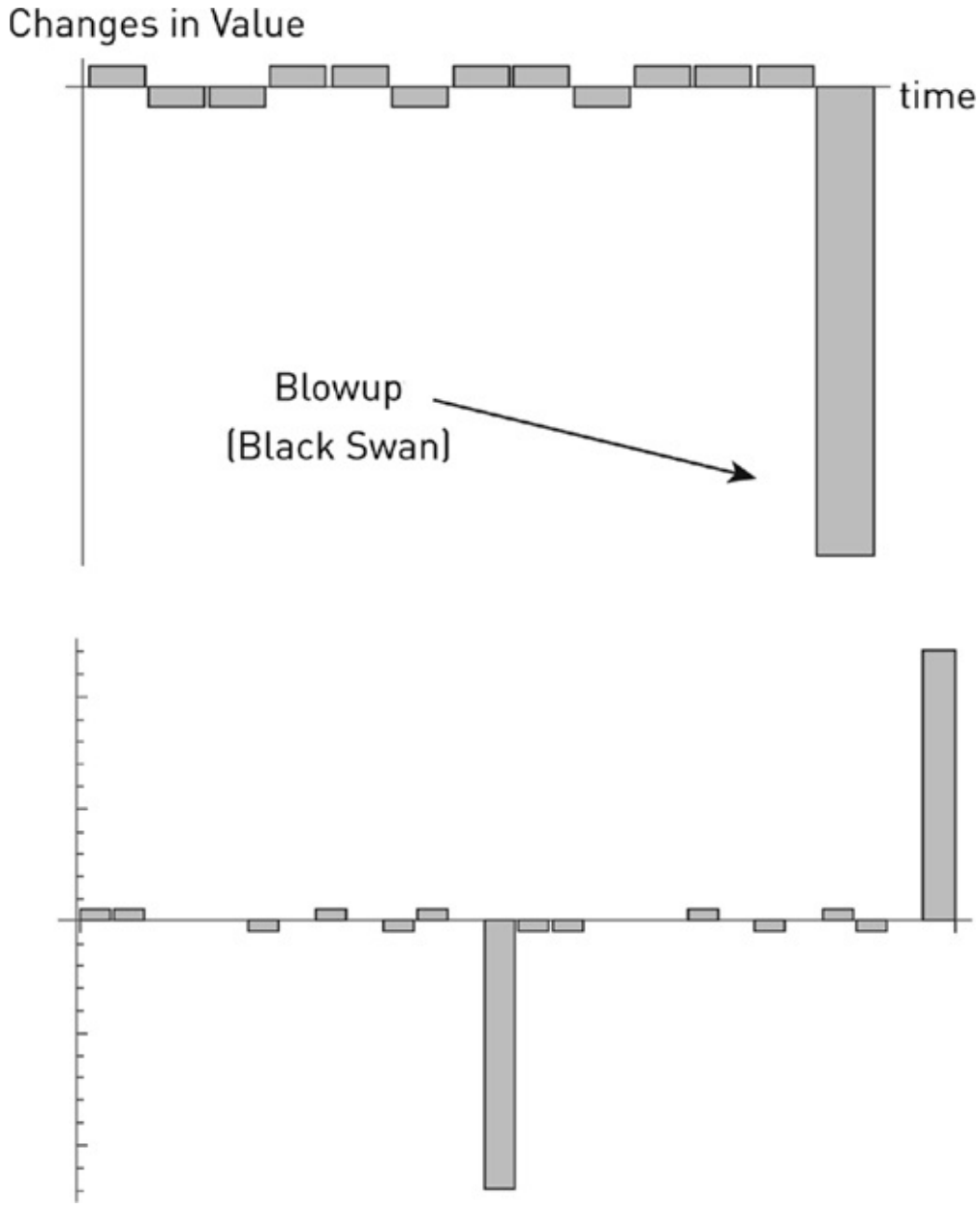


FIGURE 20. ***Fragile variations through time, two types of fragilities.*** *A representative series. The horizontal axis shows time, the vertical one shows variations. This can apply to anything: a health indicator, changes in wealth, your happiness, etc. We can see small (or no) benefits and variations most of the time and occasional large adverse outcomes. Uncertainty can hit in a rather hard way. Notice that the loss can occur at any time and exceed the previous cumulative gains. Type 2 (top) and Type 1 (bottom)*

differ in that Type 2 does not experience large positive effects from uncertainty while Type 1 does.

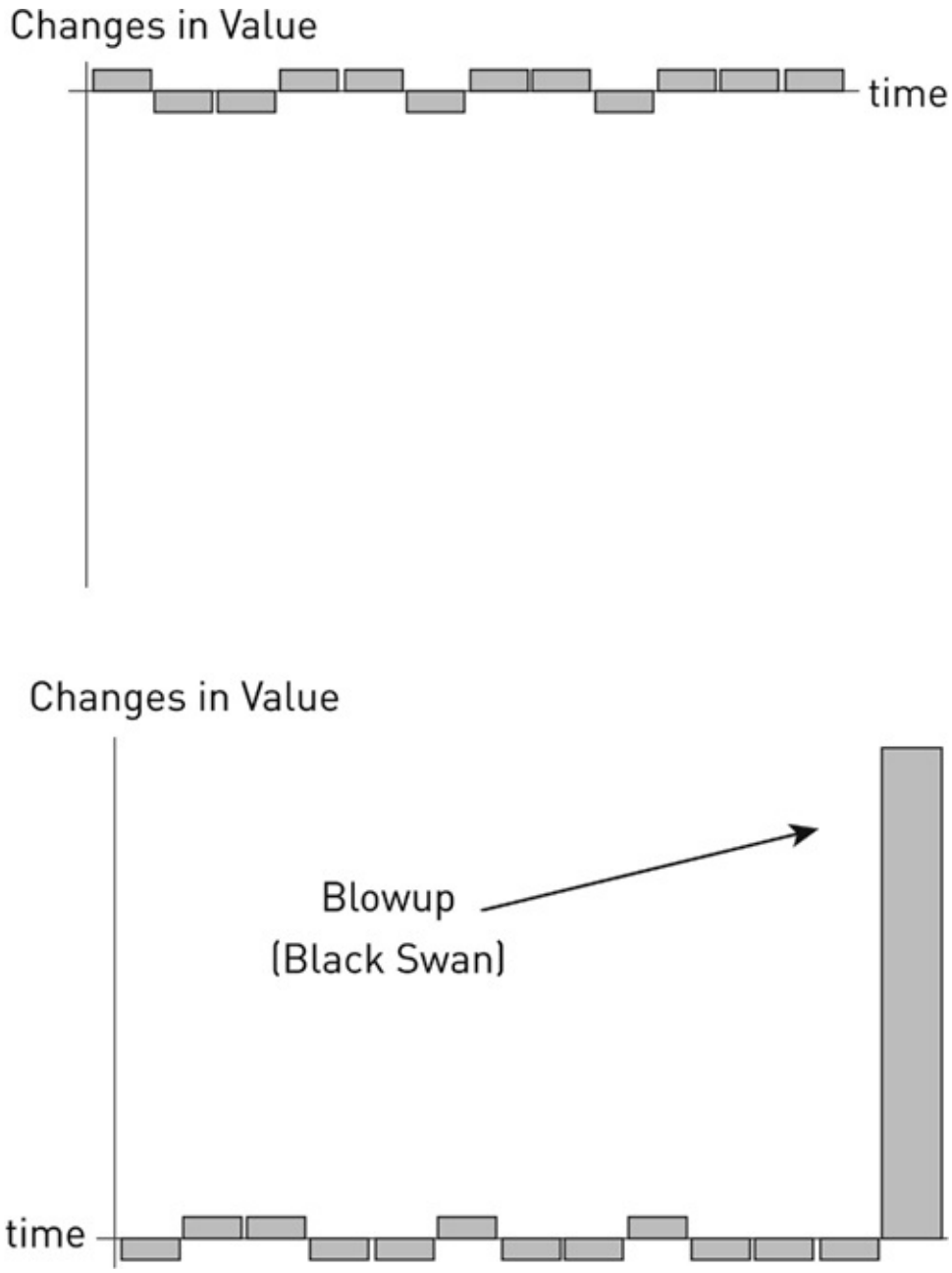


FIGURE 21. ***The Just Robust*** *(but not antifragile) (top): It experiences small or no variations through time. Never large ones.* ***The Antifragile*** *system (bottom): Uncertainty benefits a lot more than it hurts—the exact opposite of the first graph in Figure 20.*

Seen in Probabilities

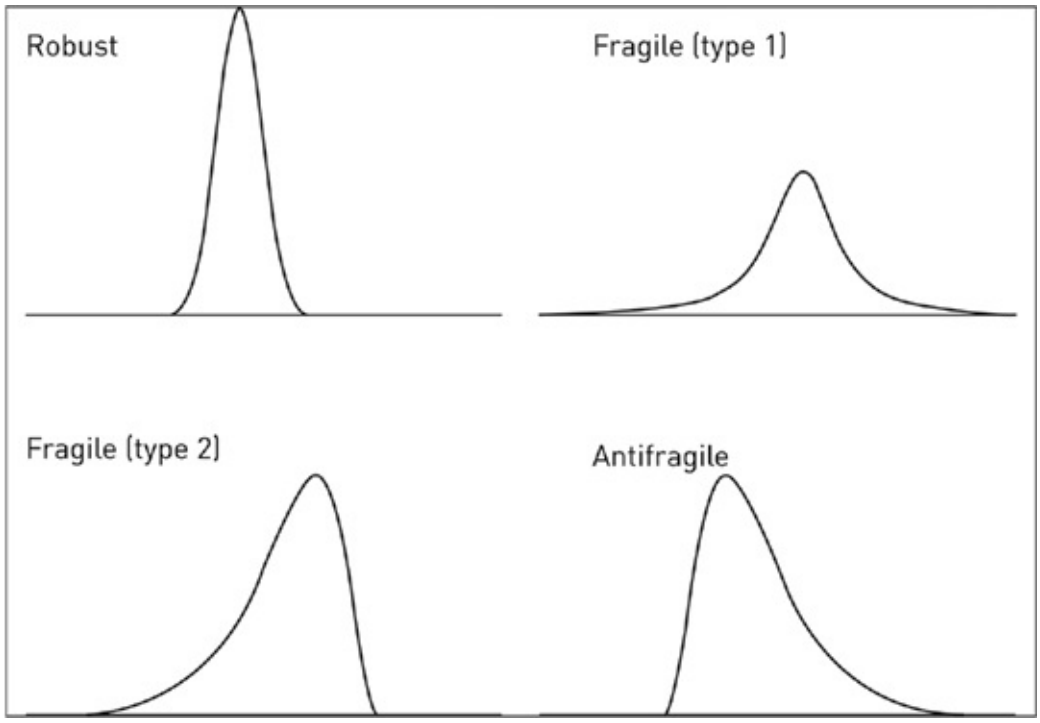


FIGURE 22. *The horizontal axis represents outcomes, the vertical their probability (i.e., their frequency).* ***The Robust:*** *Small positive and negative outcomes.* ***The Fragile*** *(**Type 1**, very rare): Can deliver both large negative and large positive outcomes. Why is it rare? Symmetry is very, very rare empirically yet all statistical distributions tend to simplify by using it.* ***The Fragile (Type 2):*** *We see large improbable downside (often hidden and ignored), small upside. There is a possibility of a severe unfavorable outcome (left), much more than a hugely favorable one, as the left side is thicker than the right one.* ***The Antifragile:*** *Large upside, small downside. Large favorable outcomes are possible, large unfavorable ones less so (if not impossible). The right "tail," for favorable outcomes, is larger than the left one.*

Click here for a larger image of this table.

TABLE 9 • THE FOUR DIFFERENT CLASSES OF PAYOFFS

Left Tail of the Distribution	*Right Tail of the Distribution*	*Condition*
Thin	Thick	Antifragile
Thick	Thick	Fragile (Type 1) [Very Rare]
Thick	Thin	Fragile (Type 2)
Thin	Thin	Robust

Fragility has a left tail and, what is crucial, is therefore sensitive to

perturbations of the left side of the probability distribution.

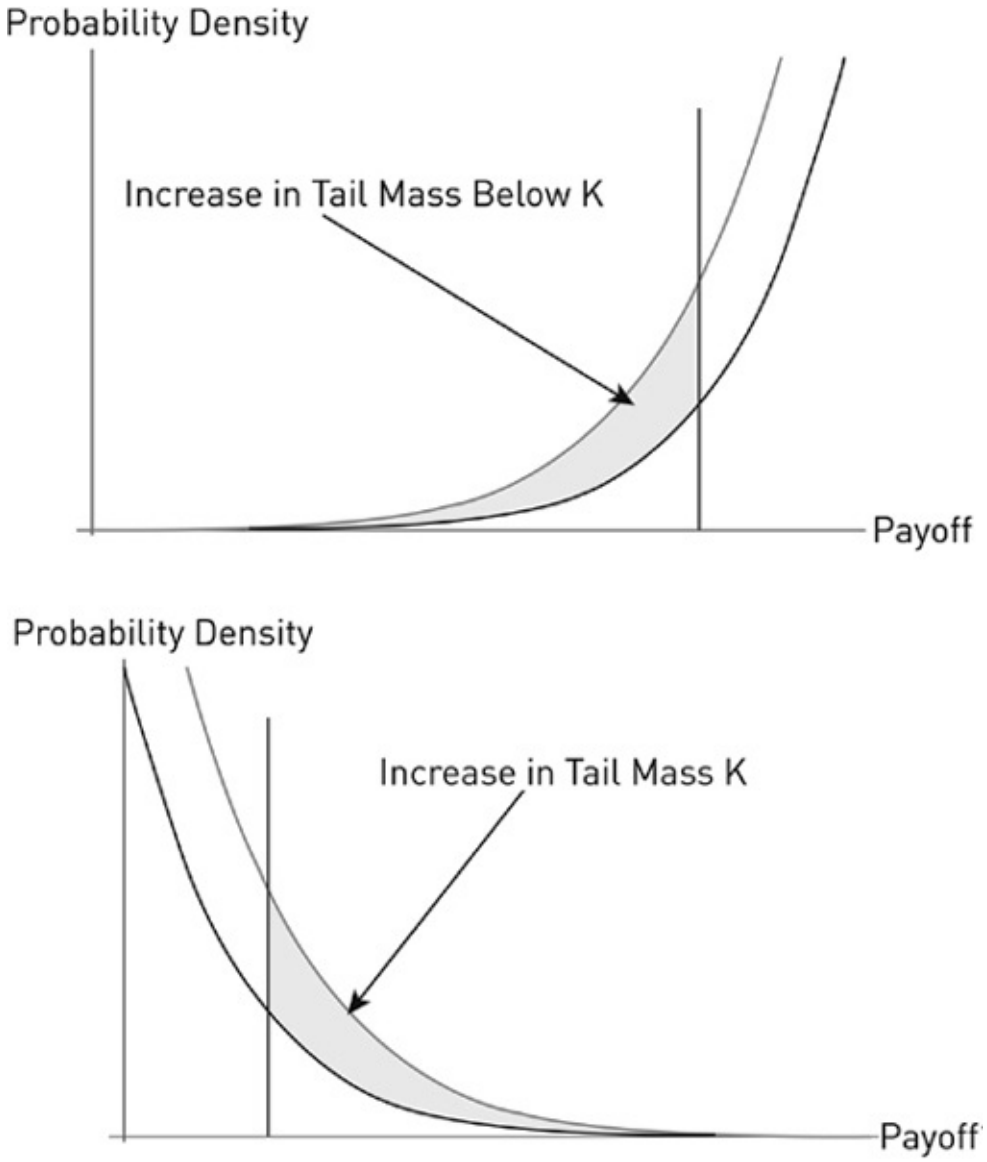


FIGURE 23. ***Definition of Fragility*** *(top graph): Fragility is the shaded area, the increase in the mass in left tail below a certain level K of the target variable in response to any change in parameter of the source variable—mostly the "volatility" or something a bit more tuned. We subsume all these changes in* s^-*, about which later in the notes section (where I managed to hide equations).*

For a ***definition of antifragility*** *(bottom graph), which is not exactly symmetric, the same mirror image for right tail plus robustness in left tail. The parameter perturbated is* s^+.

It is key that while we may not be able to specify the probability distribution with any precision, we can probe the response through heuristics thanks to the "transfer theorem" in Taleb and Douady (2012). In other words, we do not need to understand the future probability of events, but we can figure out the fragility to these events.

BARBELL TRANSFORMATION IN TIME SERIES

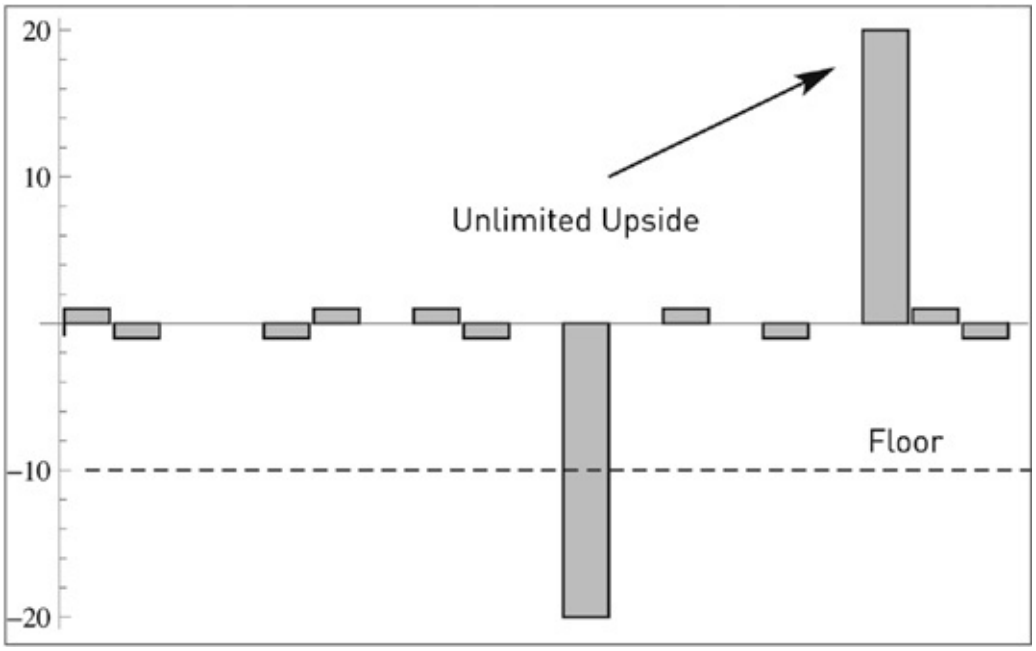
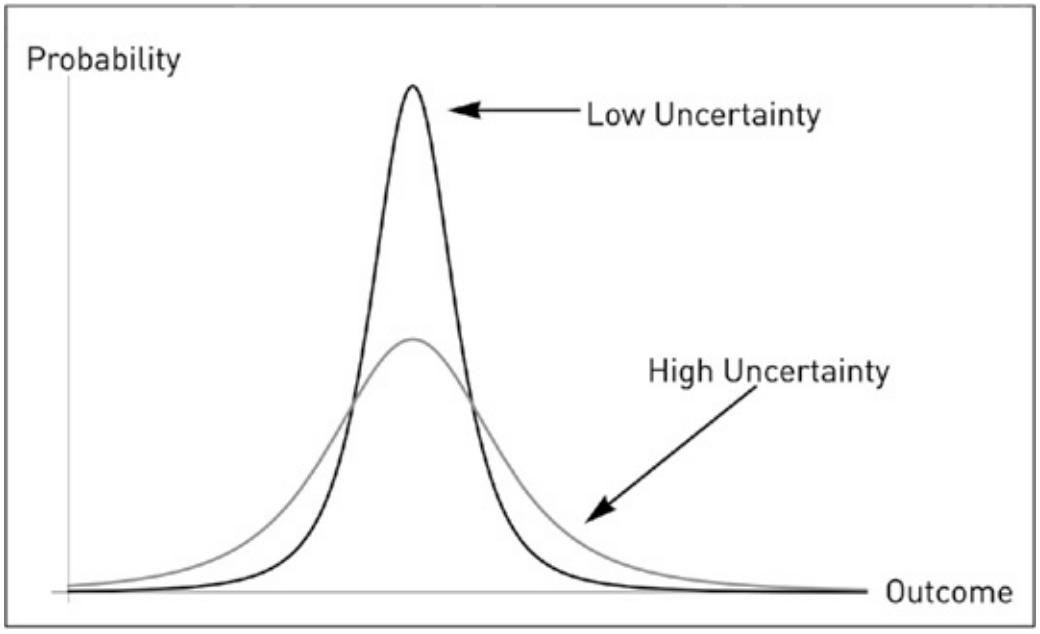


FIGURE 24. *Barbell seen in time series space. Flooring payoffs while keeping upside.*

BARBELLS (CONVEX TRANSFORMATIONS) AND THEIR PROPERTIES IN PROBABILITY SPACE



A graphical expression of the barbell idea.

FIGURE 25. *Case 1, **the Symmetric Case.** Injecting uncertainty into the system makes us move from one bell shape—the first, with narrow possible spate of outcomes—to the second, a lower peak but more spread out. So it causes an increase of both positive and negative surprises, both positive and negative Black Swans.*

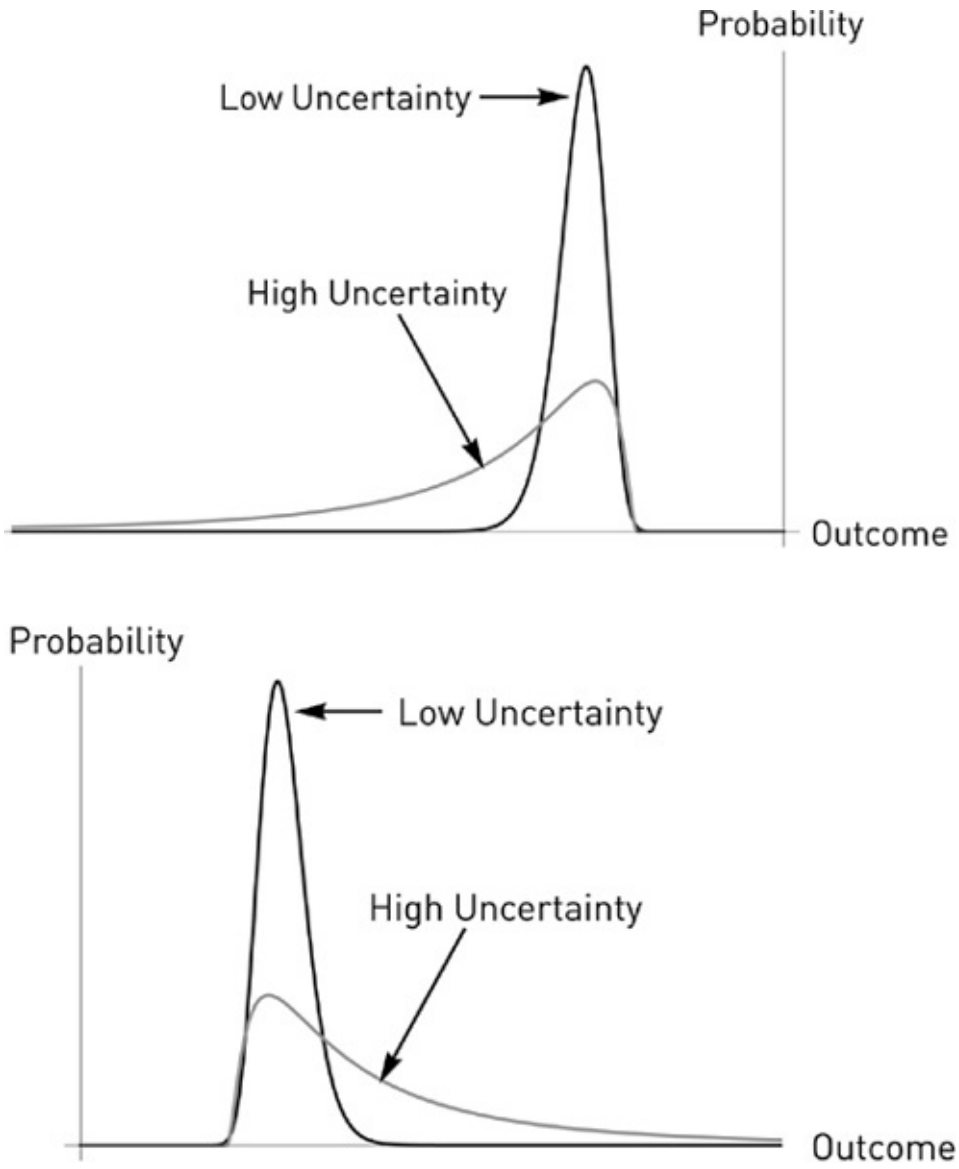


FIGURE 26. *Case 2 (top):* ***Fragile.*** *Limited gains, larger losses. Increasing uncertainty in the system causes an augmentation of mostly (sometimes only) negative outcomes, just negative Black Swans. Case 3 (bottom): Antifragile. Increasing randomness and uncertainty in the system raises the probability of very favorable outcomes, and accordingly expand the expected payoff. It shows how discovery is, mathematically, exactly like an anti–airplane delay.*

TECHNICAL VERSION OF FAT TONY'S "NOT THE SAME 'TING,' " OR THE CONFLATION OF EVENTS AND EXPOSURE TO EVENTS

This note will also explain a "convex transformation."

$f(x)$ is *exposure* to the variable x. $f(x)$ can equivalently be called "payoff from x," "exposure to x," even "utility of payoff from x" where we introduce in f a utility function. x can be anything.

> **Example**: x is the intensity of an earthquake on some scale in some specific area, $f(x)$ is the number of persons dying from it. We can easily see that $f(x)$ can be made more predictable than x (if we force people to stay away from a specific area or build to some standards, etc.).

> **Example**: x is the number of meters of my fall to the ground when someone pushes me from height x, $f(x)$ is a measure of my physical condition from the effect of the fall. Clearly I cannot predict x (who will push me, rather $f(x)$).

> **Example**: x is the number of cars in NYC at noon tomorrow, $f(x)$ is travel time from point A to point B for a certain agent. $f(x)$ can be made more predictable than x (take the subway, or, even better, walk).

Some people talk about $f(x)$ thinking they are talking about x. This is the problem of the **conflation of event and exposure**. This error present in Aristotle is virtually ubiquitous in the philosophy of probability (say, Hacking).

One can become antifragile to x without understanding x, through convexity of $f(x)$.

The answer to the question "what do you do in a world you don't understand?" is, simply, work on the undesirable states of $f(x)$.

It is often easier to modify $f(x)$ than to get better knowledge of x. (In other words, robustification rather than forecasting Black Swans.)

> **Example**: If I buy an insurance on the market, here x, dropping more than 20 percent, $f(x)$ will be independent of the part of the probability distribution of x that is below 20 percent and impervious to changes in its scale parameter. (This is an example of a barbell.)

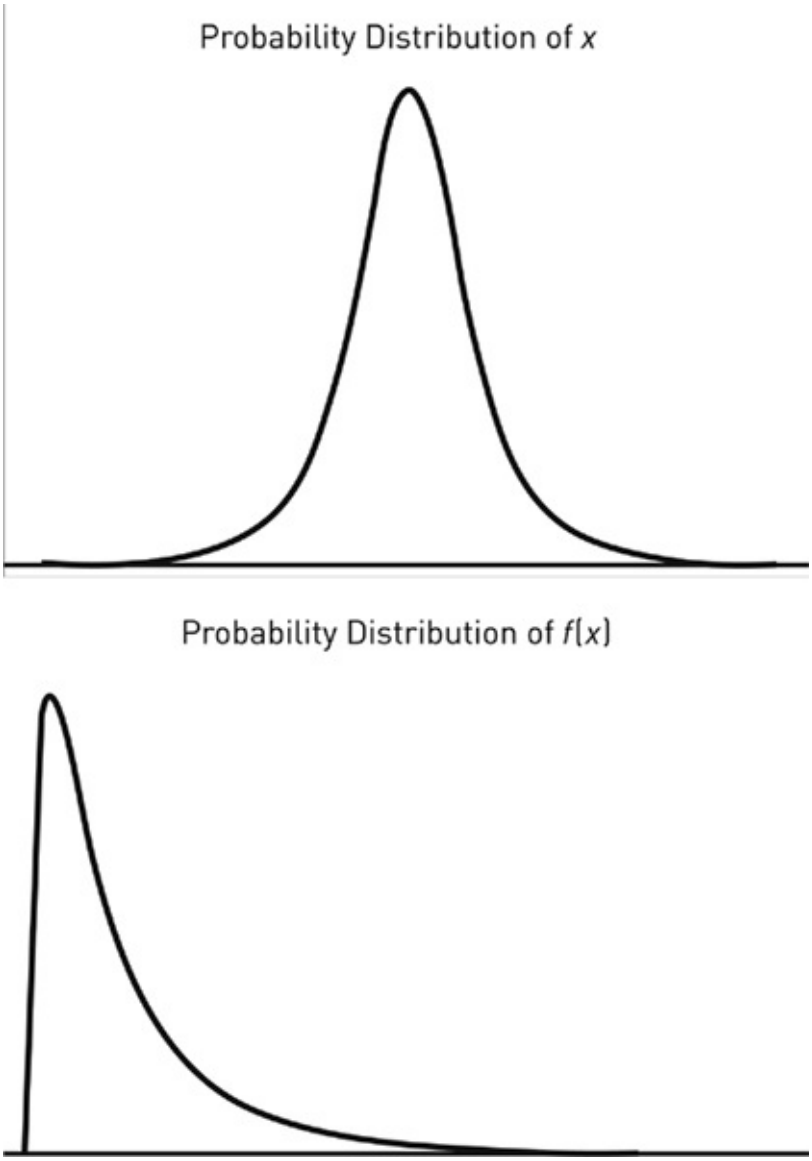


FIGURE 27. ***Convex Transformation (f(x) is a convex function of x).*** *The difference between x and exposure to x. There is no downside risk in the second graph. The key is to modify f(x) in order to make knowledge of the properties of x on the left side of the distribution as irrelevant as possible. This operation is called convex transformation, nicknamed "barbell" here.*

Green lumber fallacy: When one confuses $f(x)$ for another function $g(x)$, one that has different nonlinearities.

More technically: If one is antifragile to x, then the variance (or volatility, or other measures of variation) of x benefit $f(x)$, since distributions that are skewed have their mean depend on the variance and when skewed right, their expectation increases with variance (the lognormal, for instance, has for mean a

term that includes $+\frac{1}{2}\sigma^2$).

Further, the probability distribution of $f(x)$ is markedly different from that of x, particularly in the presence of nonlinearities.

When $f(x)$ is convex (concave) monotonically, $f(x)$ is right (left) skewed.

When $f(x)$ is increasing and convex on the left then concave to the right, the probability distribution of $f(x)$ is thinner-tailed than that of x. For instance, in Kahneman-Tversky's prospect theory, the so-called utility of changes in wealth is more "robust" than that of wealth.

Why payoff matters more than probability (technical): Where $p(x)$ is the density, the expectation, that is $\int f(x)p(x)dx$, will depend increasingly on f rather than p, and the more nonlinear f, the more it will depend on f rather than p.

THE FOURTH QUADRANT (TALEB, 2009)

The idea is that tail events are not computable (in fat-tailed domains), but we can assess our exposure to the problem. Assume $f(x)$ is an increasing function, Table 10 connects the idea to the notion of the Fourth Quadrant.

Click here for a larger image of this table.

TABLE 10

	THIN-TAILED DISTRIBUTION FOR X	*FAT-TAILED DISTRIBUTION FOR X*
$f(x)$ "mitigating" by clipping extreme outcomes, i.e., convex-concave	Very robust outcome	Quite robust outcome
$f(x)$ concave-convex, exacerbates remote outcomes	Robust outcome (sort of)	FOURTH QUADRANT Fragile (if $f(x)$ is concave) or antifragile

LOCAL AND GLOBAL CONVEXITIES (TECHNICAL)

Nothing is open-ended in nature—death is a maximum outcome for a unit. So things end up convex on one end, concave on the other.

In fact, there is maximum harm at some point in things biological. Let us revisit the concave figure of the stone and pebbles in Chapter 18: by widening the range we see that boundedness of harm brings convexities somewhere. Concavity was dominant, but local. Figure 28 looks at the continuation of the story of the stone and pebbles.

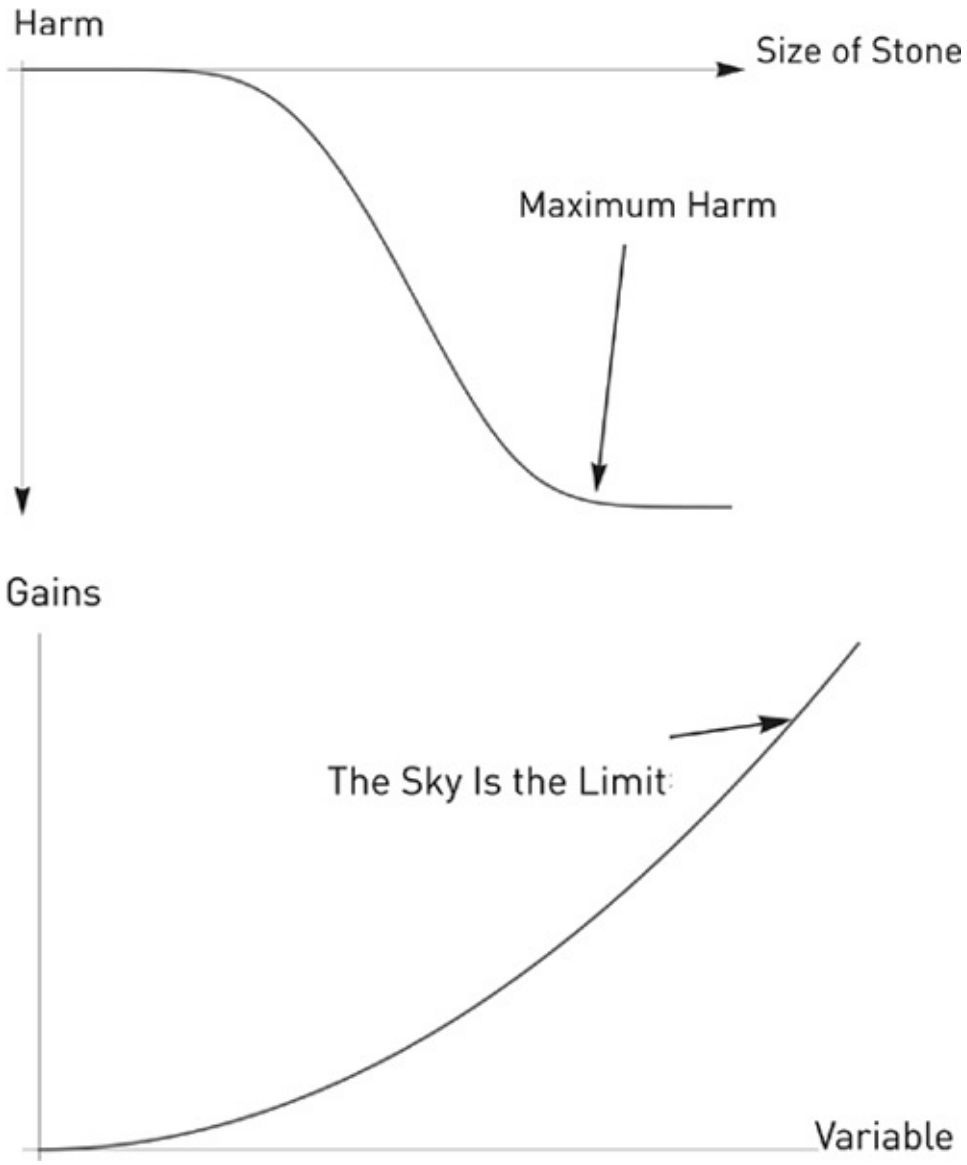


FIGURE 28. *The top graph shows a broader range in the story of the stone and pebbles in Chapter 18. At some point, the concave turns convex as we hit maximum harm. The bottom graph shows strong antifragility, with no known upper limit (leading to Extremistan). These payoffs are only available in economic variables, say, sales of books, or matters unbounded or near-unbounded. I am unable to find such an effect in nature.*

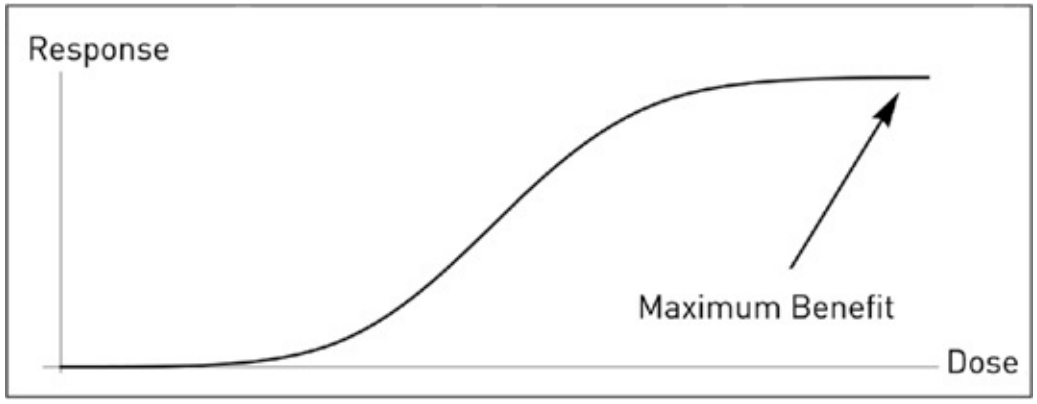


FIGURE 29. ***Weak Antifragility (Mediocristan), with bounded maximum.*** *Typical in nature.*

FREAK NONLINEARITIES (VERY TECHNICAL)

The next two types of nonlinearities are almost never seen outside of economic variables; they are particularly limited to those caused by derivatives.

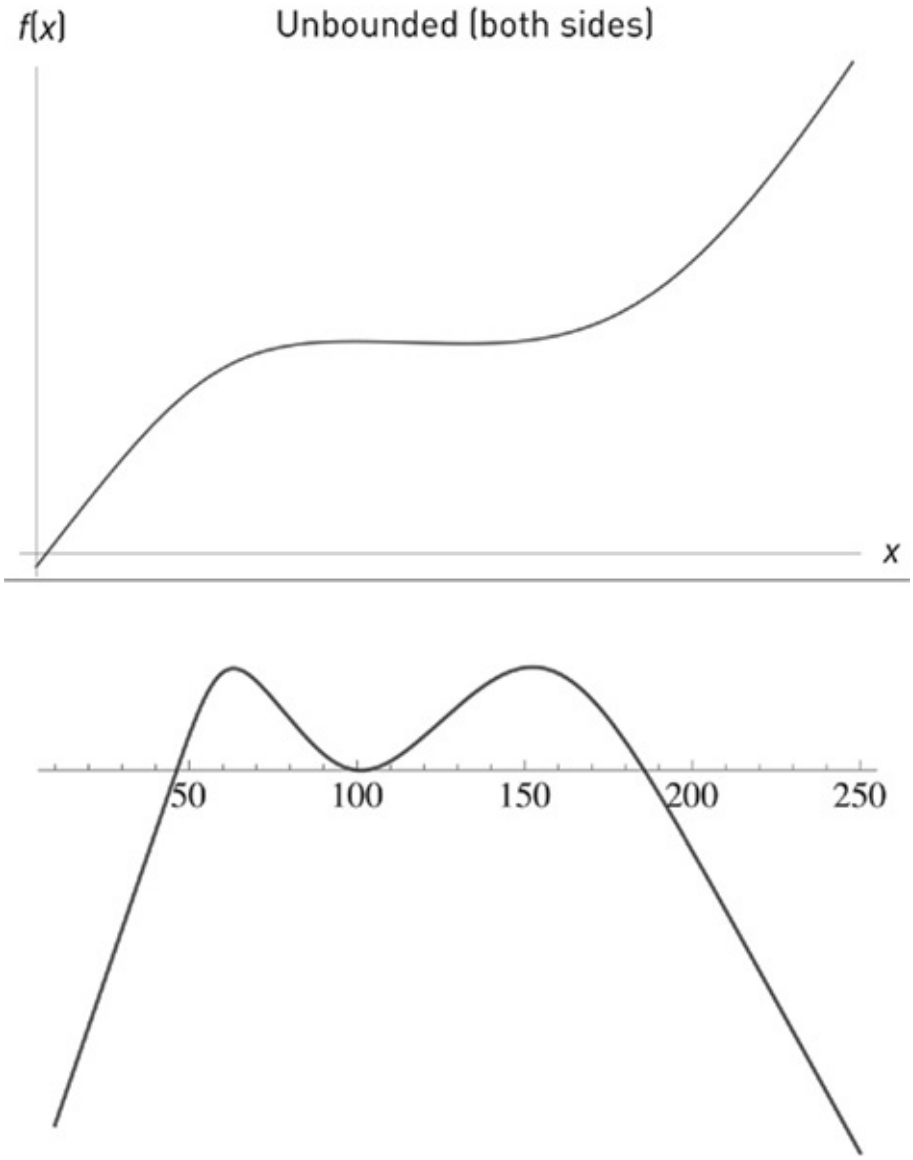


FIGURE 30. *The top graph shows a convex-concave increasing function, the opposite of the bounded dose-response functions we see in nature. It leads to Type 2, Fragile (very, very fat tails). The bottom graph shows the most dangerous of all: pseudoconvexity. Local antifragility, global fragility.*

MEDICAL NONLINEARITIES AND THEIR PROBABILITY CORRESPONDENCE (CHAPTERS 21 & 22)

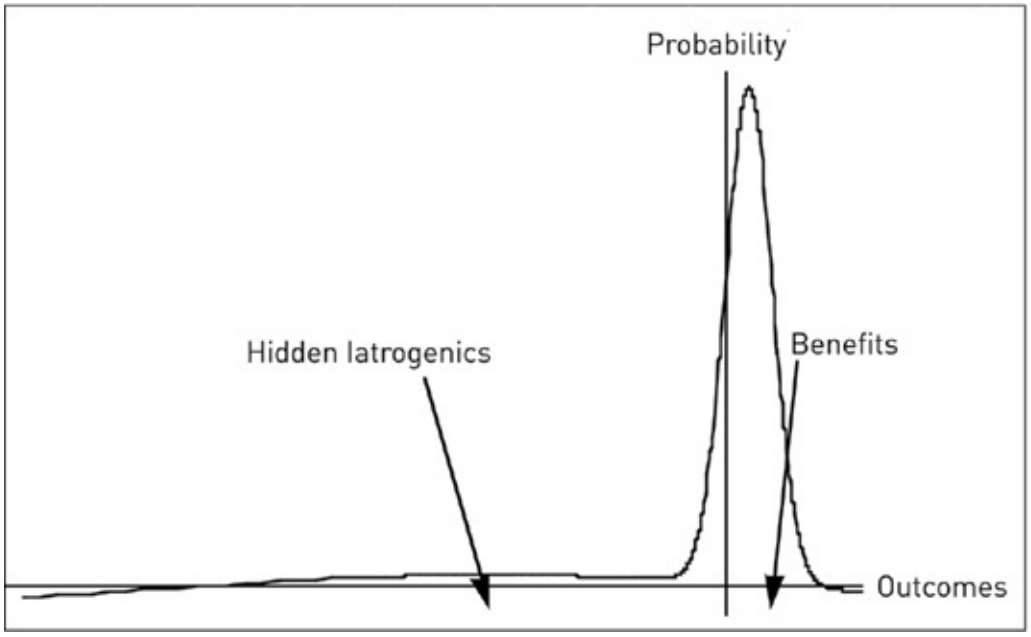


FIGURE 31. ***Medical Iatrogenics:*** *Case of small benefits and large Black Swan–style losses seen in probability space. Iatrogenics occurs when we have small identifiable gains (say, avoidance of small discomfort or a minor infection) and exposure to Black Swans with delayed invisible large side effects (say, death). These concave benefits from medicine are just like selling a financial option (plenty of risk) against small tiny immediate gains while claiming "evidence of no harm."*

In short, for a healthy person, there is a small probability of disastrous outcomes (discounted because unseen and not taken into account), and a high probability of mild benefits.

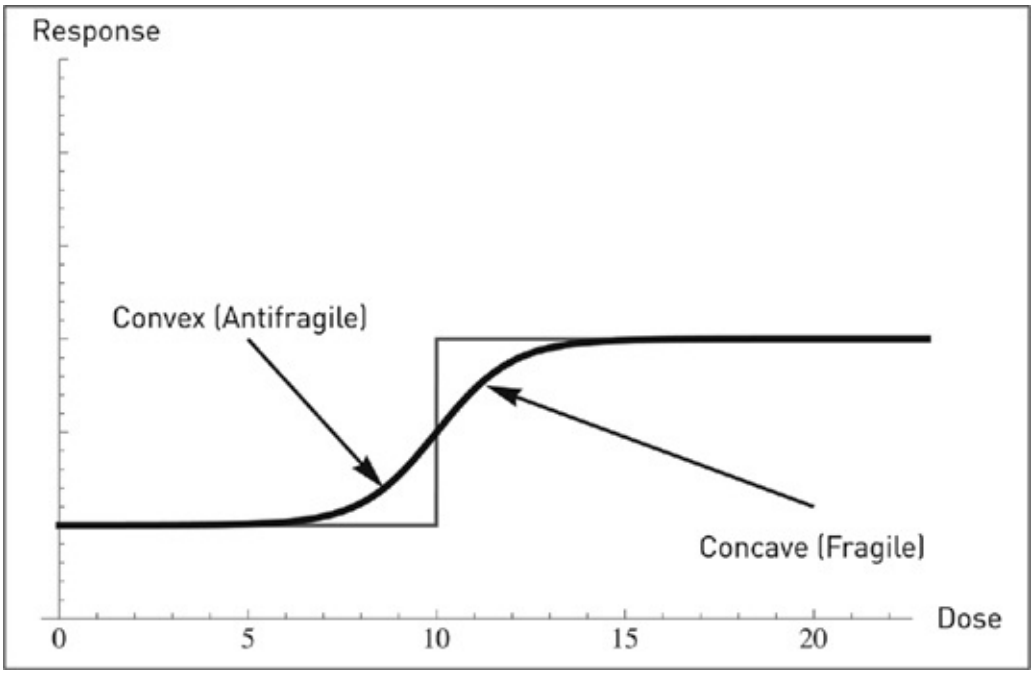


FIGURE 32. ***Nonlinearities in biology.*** *The shape convex-concave necessarily flows from anything increasing (monotone, i.e., never decreasing) and bounded, with maximum and minimum values, i.e., does not reach infinity from either side. At low levels, the dose response is convex (gradually more and more effective). Additional doses tend to become gradually ineffective or start hurting. The same can apply to anything consumed in too much regularity. This type of graph necessarily applies to any situation bounded on both sides, with a known minimum and maximum (saturation), which includes happiness.*

For instance, if one considers that there exists a maximum level of happiness and unhappiness, then the general shape of this curve with convexity on the left and concavity on the right has to hold for happiness (replace "dose" with "wealth" and "response" with "happiness"). Kahneman-Tversky prospect theory models a similar shape for "utility" of changes in wealth, which they discovered empirically.

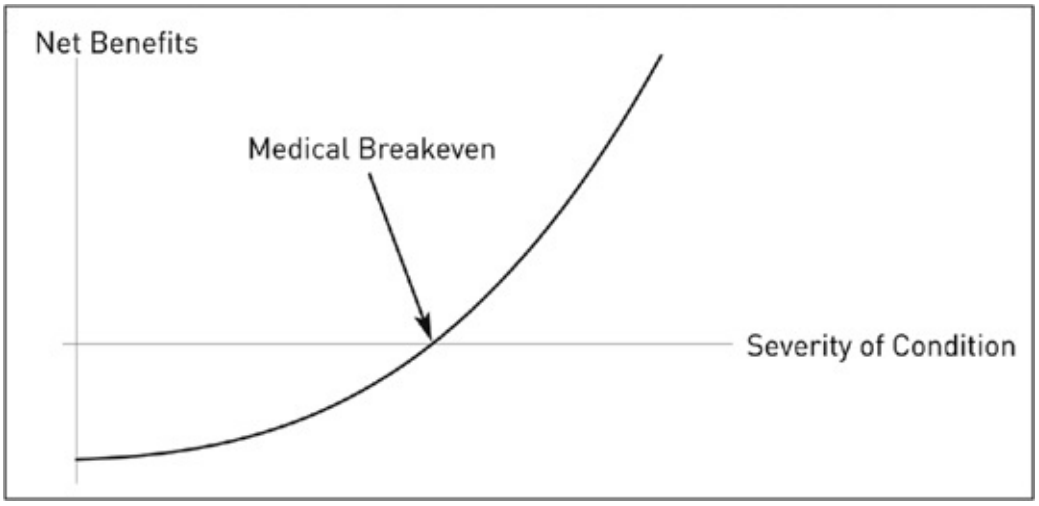


FIGURE 33. *Recall the hypertension example. On the vertical axis, we have the benefits of a treatment, on the horizontal, the severity of the condition. The arrow points at the level where probabilistic gains match probabilistic harm. Iatrogenics disappears nonlinearly as a function of the severity of the condition. This*

implies that when the patient is very ill, the distribution shifts to antifragile (thicker right tail), with large benefits from the treatment over possible iatrogenics, little to lose.

Note that if you increase the treatment you hit concavity from maximum benefits, a zone not covered in the graph—seen more broadly, it would look like the preceding graph.

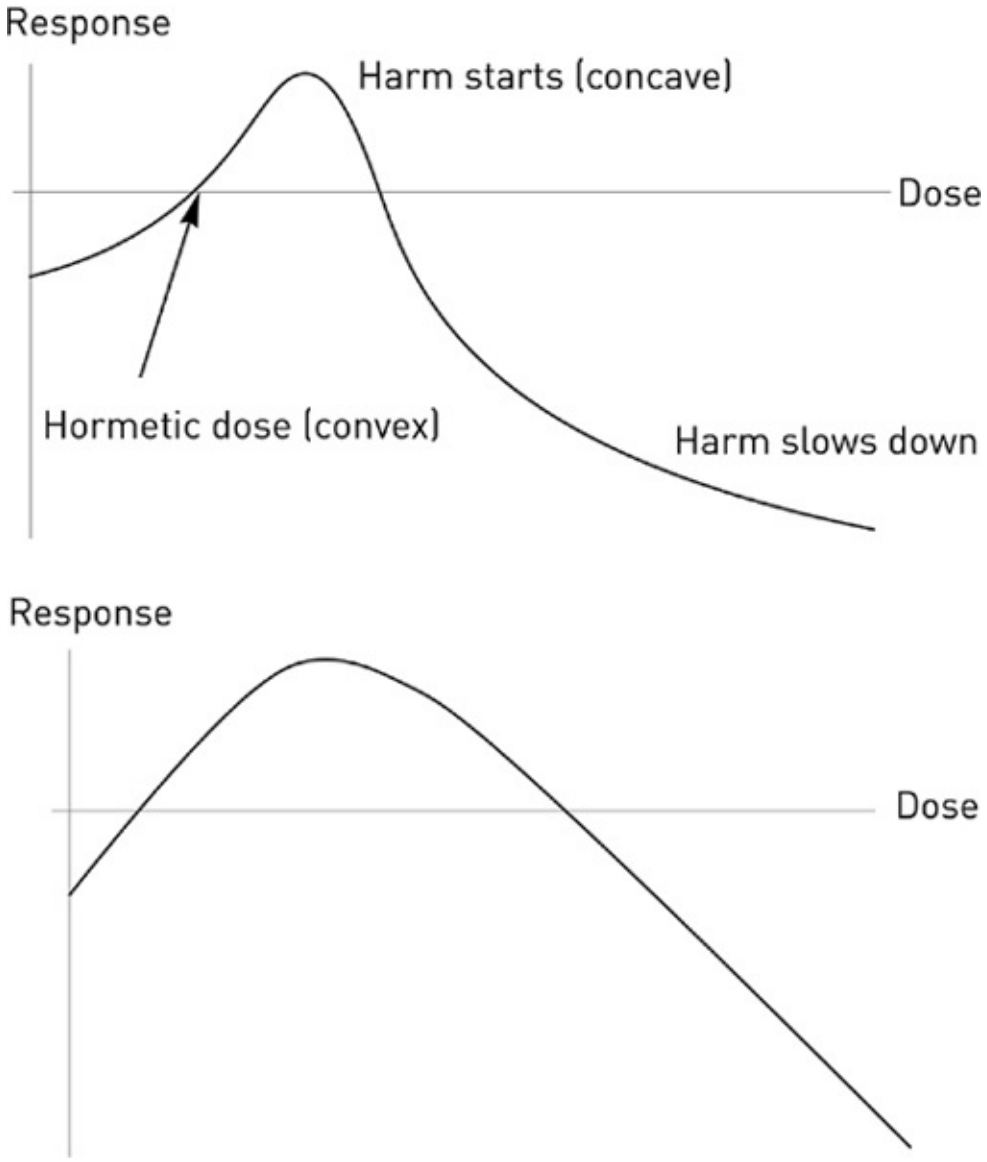


FIGURE 34. *The top graph shows hormesis for an organism (similar to Figure 19): we can see a stage of benefits as the dose increases (initially convex) slowing down into a phase of harm as we increase the dose a bit further (initially concave); then we see things flattening out at the level of maximum harm (beyond a certain point, the organism is dead so there is such a thing as a bounded and known worst case scenario in biology). To the right, a wrong graph of hormesis in medical textbooks showing initial concavity, with a beginning that looks linear or slightly concave.*

THE INVERSE TURKEY PROBLEM

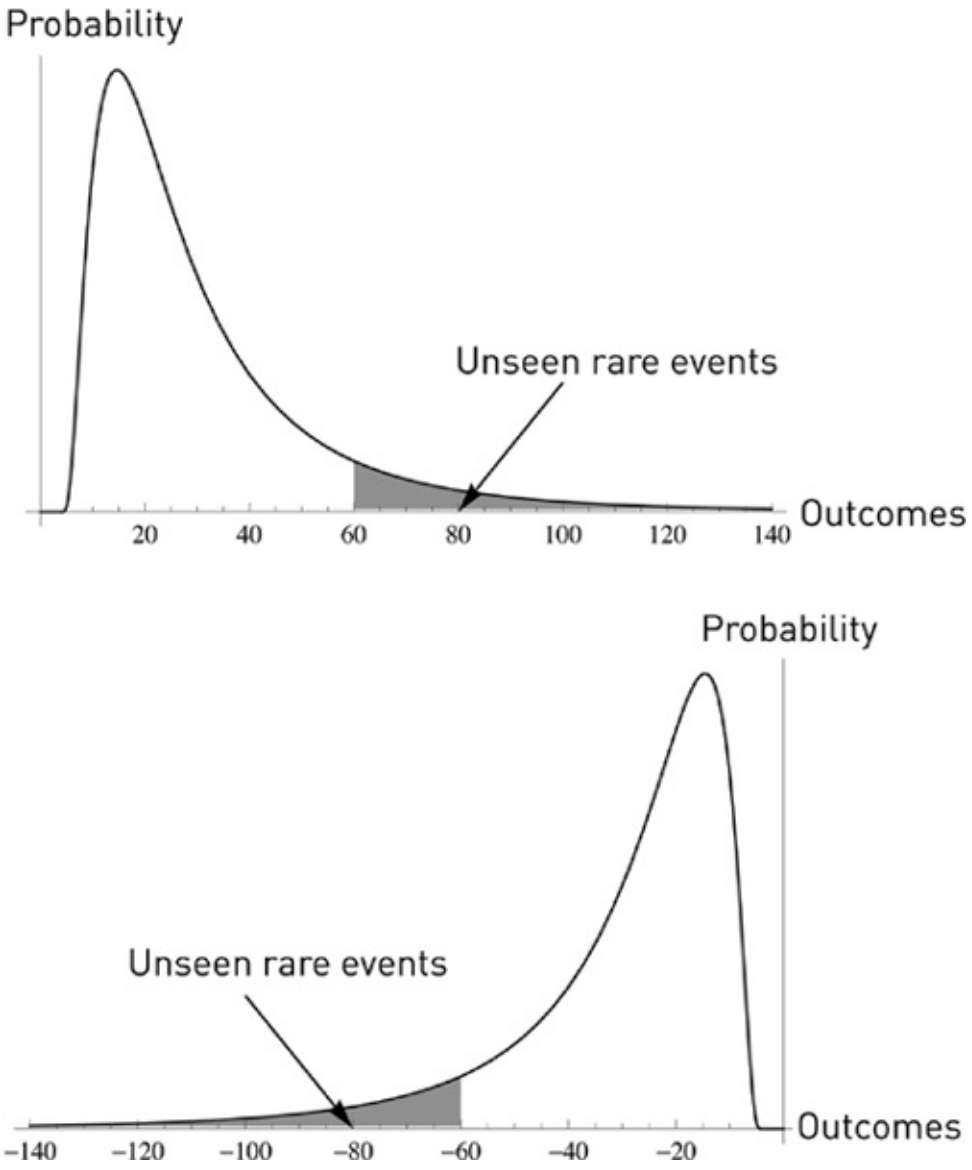


FIGURE 35. ***Antifragile, Inverse Turkey Problem:*** *The unseen rare event is positive. When you look at a positively skewed (antifragile) time series and make inferences about the unseen, you miss the good stuff and underestimate the benefits (the Pisano, 2006a, 2006b, mistake). On the bottom, the other Harvard problem, that of Froot (2001). The filled area corresponds to what we do not tend to see in small samples, from insufficiency of points. Interestingly the shaded area increases with model error. The more technical sections call this zone* ω_B *(turkey) and* ω_C *(inverse turkey).*

DIFFERENCE BETWEEN POINT ESTIMATES AND DISTRIBUTIONS

Let us apply this analysis to how planners make the mistakes they make, and why deficits tend to be worse than planned:

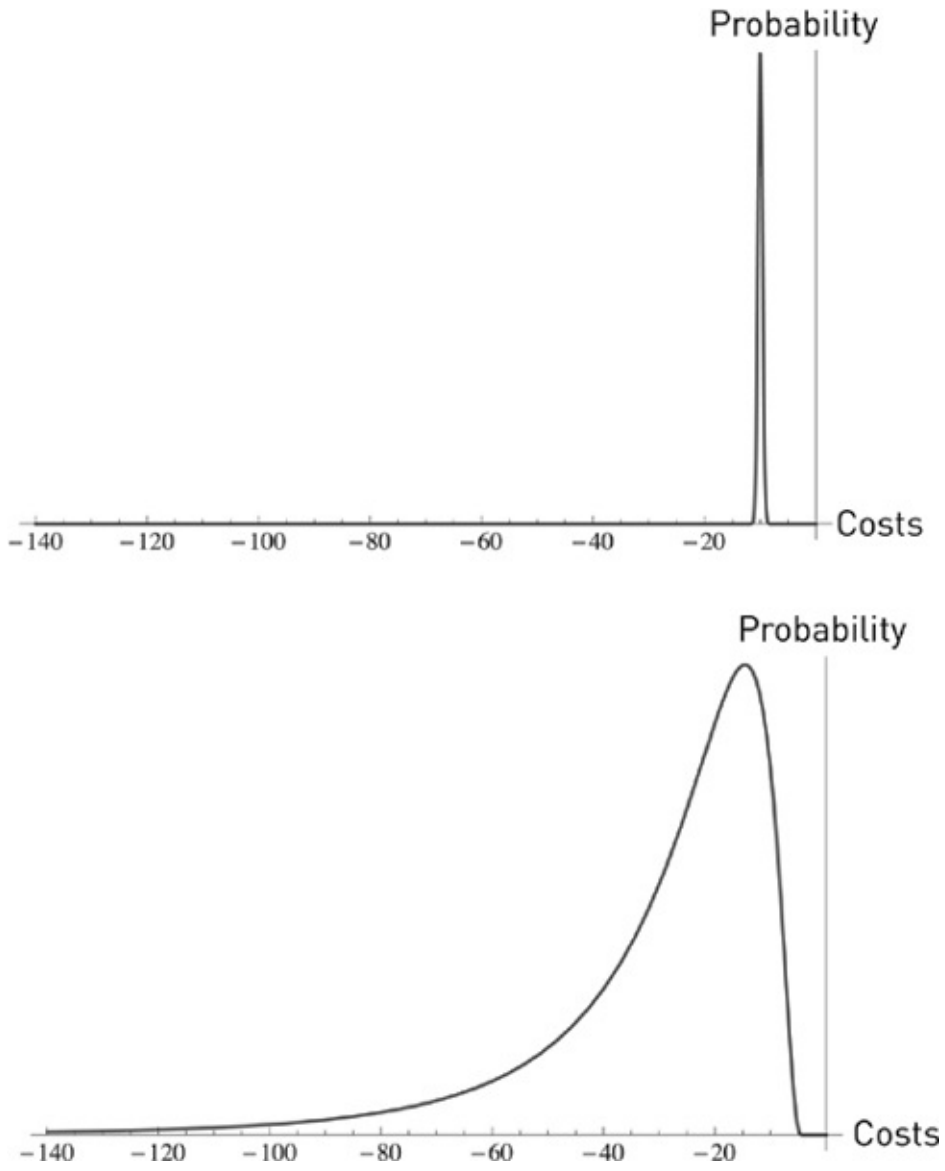


FIGURE 36. ***The gap between predictions and reality:*** *probability distribution of outcomes from costs of projects in the minds of planners (top) and in reality (bottom). In the first graph they assume that the costs will be both low and quite certain. The graph on the bottom shows outcomes to be both worse and more spread out, particularly with higher possibility of unfavorable outcomes. Note the fragility increase owing to the swelling left tail.*

This misunderstanding of the effect of uncertainty applies to government deficits, plans that have IT components, travel time (to a lesser degree), and many more. We will use the same graph to show model

error from underestimating fragility by assuming that a parameter is constant when it is random. This is what plagues bureaucrat-driven economics (next discussion).

Appendix II (Very Technical):

WHERE MOST ECONOMIC MODELS FRAGILIZE AND BLOW PEOPLE UP

When I said "technical" in the main text, I may have been fibbing. Here I am not.

The Markowitz incoherence: Assume that someone tells you that the probability of an event is exactly zero. You ask him where he got this from. "Baal told me" is the answer. In such case, the person is coherent, but would be deemed unrealistic by non-Baalists. But if on the other hand, the person tells you "I *estimated* it to be zero," we have a problem. The person is both unrealistic and inconsistent. Something estimated needs to have an estimation error. So probability cannot be zero if it is estimated, its lower bound is linked to the estimation error; the higher the estimation error, the higher the probability, up to a point. As with Laplace's argument of total ignorance, an infinite estimation error pushes the probability toward ½.

We will return to the implication of the mistake; take for now that anything estimating a parameter and then putting it into an equation is different from estimating the equation across parameters (same story as the health of the grandmother, the average temperature, here "estimated" is irrelevant, what we need is average health across temperatures). And Markowitz showed his incoherence by starting his "semi-nal" paper with "Assume you know *E* and *V*" (that is, the expectation and the variance). At the end of the paper he accepts that they need to be estimated, and what is worse, with a combination of statistical techniques and the "judgment of practical men." Well, if these parameters need to be estimated, with an error, then the derivations need to be written differently and, of course, we would have no paper—and no Markowitz paper, no blowups,

no modern finance, no fragilistas teaching junk to students.… Economic models are extremely fragile to assumptions, in the sense that a slight alteration in these assumptions can, as we will see, lead to extremely consequential differences in the results. And, to make matters worse, many of these models are "back-fit" to assumptions, in the sense that the hypotheses are selected to make the math work, which makes them ultrafragile and ultrafragilizing.

Simple example: Government deficits.

We use the following deficit example owing to the way calculations by governments and government agencies currently miss convexity terms (and have a hard time accepting it). Really, they don't take them into account. The example illustrates:

(a) missing the stochastic character of a variable known to affect the model but deemed deterministic (and fixed), and

(b) *F*, the function of such variable, is convex or concave with respect to the variable.

Say a government estimates unemployment for the next three years as averaging 9 percent; it uses its econometric models to issue a forecast balance *B* of a two-hundred-billion deficit in the local currency. But it misses (like almost everything in economics) that unemployment is a stochastic variable. Employment over a three-year period has fluctuated by 1 percent on average. We can calculate the effect of the error with the following:

Unemployment at 8%, Balance B(8%) = −75 bn (improvement of 125 bn)

Unemployment at 9%, Balance B(9%)= −200 bn

Unemployment at 10%, Balance B(10%)= −550 bn (worsening of 350 bn)

The concavity bias, or negative convexity bias, from underestimation of the deficit is −112.5 bn, since ½ {*B*(8%) + *B*(10%)} = −312 bn, not −200 bn. This is the exact case of the **inverse philosopher's stone**.

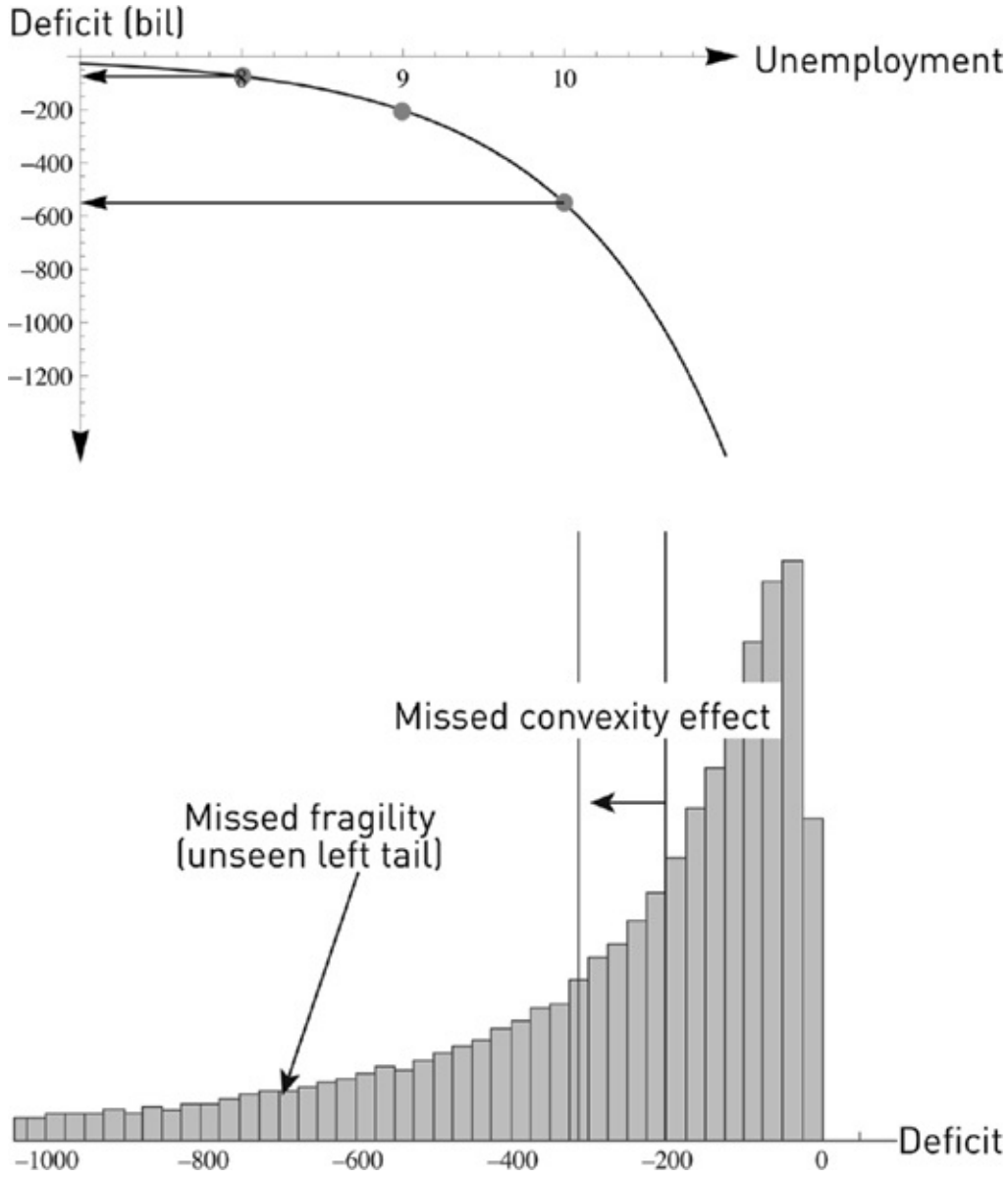


FIGURE 37. ***Nonlinear transformations allow the detection of both model convexity bias and fragility.*** *Illustration of the example: histogram from Monte Carlo simulation of government deficit as a left-tailed random variable simply as a result of randomizing unemployment, of which it is a concave function. The method of point estimate would assume a Dirac stick at −200, thus underestimating both the* ***expected*** *deficit (−312) and the tail fragility of it. (From Taleb and Douady, 2012).*

Application: Ricardian Model and Left Tail—The Price of Wine Happens to Vary

For almost two hundred years, we've been talking about an idea by the economist David Ricardo called "comparative advantage." In short, it says that a country should have a certain policy based on its comparative advantage in wine or clothes. Say a country is good at both wine and clothes, better than its

neighbors with whom it can trade freely. Then the visible *optimal* strategy would be to specialize in either wine or clothes, whichever fits the best and minimizes opportunity costs. Everyone would then be happy. The analogy by the economist Paul Samuelson is that if someone happens to be the best doctor in town and, at the same time, the best secretary, then it would be preferable to be the higher-earning doctor—as it would minimize opportunity losses—and let someone else be the secretary and buy secretarial services from him.

I agree that there are benefits in *some* form of specialization, but not from the models used to prove it. The flaw with such reasoning is as follows. True, it would be inconceivable for a doctor to become a part-time secretary just because he is good at it. But, at the same time, we can safely assume that being a doctor insures some professional stability: People will not cease to get sick and there is a higher social status associated with the profession than that of secretary, making the profession more desirable. But assume now that in a two-country world, a country specialized in wine, hoping to sell its specialty in the market to the other country, and that *suddenly the price of wine drops precipitously*. Some change in taste caused the price to change. Ricardo's analysis assumes that both the market price of wine and the costs of production remain constant, and there is no "second order" part of the story.

Click here for a larger image of this table.

TABLE 11 • RICARDO'S ORIGINAL EXAMPLE (COSTS OF PRODUCTION PER UNIT)

	CLOTH	*WINE*
Britain	100	110
Portugal	90	80

The logic: The table above shows the cost of production, normalized to a selling price of one unit each, that is, assuming that these trade at equal price (1 unit of cloth for 1 unit of wine). What looks like the paradox is as follows: that Portugal produces cloth cheaper than Britain, but should buy cloth from there instead, using the gains from the sales of wine. In the absence of transaction and transportation costs, it is efficient for Britain to produce just cloth, and Portugal to only produce wine.

The idea has always attracted economists because of its paradoxical and counterintuitive aspect. For instance, in an article “Why Intellectuals Don’t Understand Comparative Advantage” (Krugman, 1998), Paul Krugman, who fails to understand the concept himself, as this essay and his technical work show him to be completely innocent of tail events and risk management, makes fun of other intellectuals such as S. J. Gould who understand tail events albeit intuitively rather than analytically. (Clearly one cannot talk about returns and gains without discounting these benefits by the offsetting risks.) The article shows Krugman falling into the critical and dangerous mistake of confusing function of average and average of function. (Traditional Ricardian analysis assumes the variables are endogenous, but does not add a layer of stochasticity.)

Now consider the price of wine and clothes *variable*—which Ricardo did not assume—with the numbers above the unbiased average long-term value. Further assume that they follow a fat-tailed distribution. Or consider that their costs of production vary according to a fat-tailed distribution.

If the price of wine in the international markets rises by, say, 40 percent, then there are clear benefits. But should the price drop by an equal percentage, −40 percent, then massive harm would ensue, in magnitude larger than the benefits should there be an equal rise. There are concavities to the exposure—severe concavities.

And clearly, should the price drop by 90 percent, the effect would be disastrous. Just imagine what would happen to your household should you get an instant and unpredicted 40 percent pay cut. Indeed, we have had problems in history with countries specializing in some goods, commodities, and crops that happen to be not just volatile, but extremely volatile. And disaster does not necessarily come from variation in price, but problems in production: suddenly, you can’t produce the crop because of a germ, bad weather, or some other hindrance.

A bad crop, such as the one that caused the Irish potato famine in the decade around 1850, caused the death of a million and the emigration of a million more (Ireland’s entire population at the time of this writing is only about six million, if one includes the northern part). It is very hard to reconvert resources—unlike the case in the doctor-typist story, countries don’t have the ability to change. Indeed, monoculture (focus on a single crop) has turned out to be lethal in history—one bad crop leads to devastating famines.

The other part missed in the doctor-secretary analogy is that countries don’t have family and friends. A doctor has a support community, a circle of friends, a

collective that takes care of him, a father-in-law to borrow from in the event that he needs to reconvert into some other profession, a state above him to help. Countries don't. Further, a doctor has savings; countries tend to be borrowers.

So here again we have fragility to second-order effects.

Probability Matching: The idea of comparative advantage has an analog in probability: if you sample from an urn (with replacement) and get a black ball 60 percent of the time, and a white one the remaining 40 percent, the optimal strategy, according to textbooks, is to bet 100 percent of the time on black. The strategy of betting 60 percent of the time on black and 40 percent on white is called "probability matching" and considered to be an error in the decision-science literature (which I remind the reader is what was used by Triffat in Chapter 10). People's instinct to engage in probability matching appears to be sound, not a mistake. In nature, probabilities are unstable (or unknown), and probability matching is similar to redundancy, as a buffer. So if the probabilities change, in other words if there is another layer of randomness, then the optimal strategy is probability matching.

How specialization works: The reader should not interpret what I am saying to mean that specialization is not a good thing—only that one should establish such specialization after addressing fragility and second-order effects. Now I do believe that Ricardo is ultimately right, but not from the models shown. Organically, systems without top-down controls would specialize progressively, slowly, and over a long time, through trial and error, get the right amount of specialization—not through some bureaucrat using a model. To repeat, systems make small errors, design makes large ones.

So the imposition of Ricardo's insight-turned-model by some social planner would lead to a blowup; letting tinkering work slowly would lead to efficiency—true efficiency. The role of policy makers should be to, *via negativa* style, allow the emergence of specialization by preventing what hinders the process.

A More General Methodology to Spot Model Error

Model second-order effects and fragility: Assume we have the right model (which is a very generous assumption) but are uncertain about the parameters. As a generalization of the deficit/employment example used in the previous section, say we are using *f*, a simple function: $f(x|\bar{\alpha})$, where $\bar{\alpha}$ is supposed to be the average expected input variable, where we take φ as the distribution of α over its domain $\wp_\alpha$, $\bar{\alpha} = \int_{\wp_\alpha} \alpha\, \varphi(\alpha)\, d\alpha$.

The philosopher's stone: The mere fact that α is uncertain (since it is estimated) might lead to a bias if we perturbate from the *inside* (of the integral), i.e., stochasticize the parameter deemed fixed. Accordingly, the convexity bias is easily measured as the difference between (a) the function f integrated across values of potential α, and (b) f estimated for a single value of α deemed to be its average. The convexity bias (philosopher's stone) ω_A becomes:[1]

$$\omega_A \equiv \int_{\wp_x}\int_{\wp_\alpha} f\left(x|\,\alpha\right)\varphi(\alpha)\,d\alpha\,dx - \int_{\wp_x} f(x\left|\left(\int_{\wp_\alpha}\alpha\;\varphi(\alpha)\,d\alpha\right)\right.)dx$$

The central equation: Fragility is a partial philosopher's stone below K, hence ω_B the missed fragility is assessed by comparing the two integrals below K in order to capture the effect on the left tail:

$$\omega_B(K) \equiv \int_{-\infty}^{K}\int_{\wp_\alpha} f\left(x\,|\,\alpha\right)\varphi(\alpha)\,d\alpha\,dx - \int_{-\infty}^{K} f(x\left|\left(\int_{\wp_\alpha}\alpha\;\varphi(\alpha)\,d\alpha\right)\right.)dx$$

which can be approximated by an interpolated estimate obtained with two values of α separated from a midpoint by $\Delta\alpha$ its mean deviation of α and estimating

$$\omega_B(K) \equiv \int_{-\infty}^{K}\frac{1}{2}\left(f\left(x\,|\,\bar{\alpha}+\Delta\alpha\right)+f\left(x\,|\,\bar{\alpha}-\Delta\alpha\right)\right)dx - \int_{-\infty}^{K} f(x\,|\,\bar{\alpha})\,dx$$

Note that antifragility ω_C is integrating from K to infinity. We can probe ω_B by point estimates of f at a level of $X \le K$

$$\omega'_B(X) = \frac{1}{2}\left(f\left(X\,|\,\bar{\alpha}+\Delta\alpha\right)+f\left(X\,|\,\bar{\alpha}-\Delta\alpha\right)\right) - f(X\,|\,\bar{\alpha})$$

so that

$$\omega_B(K) = \int_{-\infty}^{K}\omega'_B(x)dx$$

which leads us to the fragility detection heuristic (Taleb, Canetti, et al., 2012). In particular, if we assume that $\omega'_B(X)$ has a constant sign for $X \le K$, then $\omega_B(K)$ has the same sign. The detection heuristic is a perturbation in the tails to probe fragility, by checking the function $\omega'_B(X)$ at any level X.

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TABLE 12

MODEL	*SOURCE OF FRAGILITY*	*REMEDY*
Portfolio theory, mean-variance, etc.	Assuming knowledge of the parameters, not integrating models across parameters, relying on (very unstable) correlations. Assumes ω_A (bias) and ω_B (fragility) = 0	1/n (spread as large a number of exposures as manageable), barbells, progressive and organic construction, etc.
Ricardian comparative advantage	Missing layer of randomness in the price of wine may imply total reversal of allocation. Assumes ω_A (bias) and ω_B (fragility) = 0	Natural systems find their own allocation through tinkering
Samuelson optimization	Concentration of sources of randomness under concavity of loss function. Assumes ω_A (bias) and ω_B (fragility) = 0	Distributed randomness
Arrow-Debreu lattice state-space	Ludic fallacy: assumes exhaustive knowledge of outcomes and knowledge of probabilities. Assumes ω_A (bias), ω_B (fragility), and ω_C (antifragility) = 0	Use of metaprobabilities changes entire model implications
Dividend cash flow models	Missing stochasticity causing convexity effects. Mostly considers ω_C (antifragility) =0	Heuristics

Portfolio fallacies: Note one fallacy promoted by Markowitz users: *portfolio theory entices people to diversify, hence it is better than nothing*. Wrong, you finance fools: it pushes them to optimize, hence overallocate. It does not drive people to take less risk based on diversification, but causes them to take more open positions owing to perception of offsetting statistical properties—making them vulnerable to model error, and especially vulnerable to the underestimation of tail events. To see how, consider two investors facing a choice of allocation across three items: cash, and securities *A* and *B*. The investor who does not know the statistical properties of *A* and *B* and knows he doesn't know will allocate, say, the portion he does not want to lose to cash, the rest into *A* and *B*—according to whatever heuristic has been in traditional use. The investor who

thinks he knows the statistical properties, with parameters σ_A, σ_B, $\rho_{A,B}$, will allocate ω_A, ω_B in a way to put the total risk at some target level (let us ignore the expected return for this). The lower his perception of the correlation $\rho_{A,B}$, the worse his exposure to model error. Assuming he thinks that the correlation $\rho_{A,B}$, is 0, he will be overallocated by $\frac{1}{3}$ for extreme events. But if the poor investor has the illusion that the correlation is −1, he will be maximally overallocated to his *A* and *B* investments. If the investor uses leverage, we end up with the story of Long-Term Capital Management, which turned out to be fooled by the parameters. (In real life, unlike in economic papers, things tend to change; for Baal's sake, they change!) We can repeat the idea for each parameter σ and see how lower perception of this σ leads to overallocation.

I noticed as a trader—and obsessed over the idea—that correlations were never the same in different measurements. Unstable would be a mild word for them: 0.8 over a long period becomes −0.2 over another long period. A pure sucker game. At times of stress, correlations experience even more abrupt changes—without any reliable regularity, in spite of attempts to model "stress correlations." Taleb (1997) deals with the effects of stochastic correlations: One is only safe shorting a correlation at 1, and buying it at −1—which seems to correspond to what the 1/*n* heuristic does.

Kelly Criterion vs. Markowitz: In order to implement a full Markowitz-style optimization, one needs to know the entire joint probability distribution of all assets for the entire future, plus the exact utility function for wealth at all future times. And without errors! (We saw that estimation errors make the system explode.) Kelly's method, developed around the same period, requires no joint distribution or utility function. In practice one needs the ratio of expected profit to worst-case return—dynamically adjusted to avoid ruin. In the case of barbell transformations, the worst case is guaranteed. And model error is much, much milder under Kelly criterion. Thorp (1971, 1998), Haigh (2000).

The formidable Aaron Brown holds that Kelly's ideas were rejected by economists—in spite of the practical appeal—because of their love of general theories for all asset prices.

Note that bounded trial and error is compatible with the Kelly criterion when one has an idea of the potential return—even when one is ignorant of the returns, if losses are bounded, the payoff will be robust and the method should outperform that of Fragilista Markowitz.

Corporate Finance: In short, corporate finance seems to be based on point projections, not distributional projections; thus if one perturbates cash flow projections, say, in the Gordon valuation model, replacing the fixed—and known—growth (and other parameters) by continuously varying jumps (particularly under fat-tailed distributions), companies deemed "expensive," or those with high growth, but low earnings, could markedly increase in expected value, something the market prices heuristically but without explicit reason.

Conclusion and summary: Something the economics establishment has been missing is that having the right model (which is a very generous assumption), but being uncertain about the parameters will invariably lead to an increase in fragility in the presence of convexity and nonlinearities.

FUHGETABOUD SMALL PROBABILITIES

Now the meat, beyond economics, the more general problem with probability and its mismeasurement.

How Fat Tails (Extremistan) Come from Nonlinear Responses to Model Parameters

Rare events have a certain property—missed so far at the time of this writing. We deal with them using a model, a mathematical contraption that takes input parameters and outputs the probability. The more parameter uncertainty there is in a model designed to compute probabilities, the more small probabilities tend to be underestimated. Simply, small probabilities are convex to errors of computation, as an airplane ride is concave to errors and disturbances (remember, it gets longer, not shorter). The more sources of disturbance one forgets to take into account, the longer the airplane ride compared to the naive estimation.

We all know that to compute probability using a standard Normal statistical distribution, one needs a parameter called *standard deviation*—or something similar that characterizes the scale or dispersion of outcomes. But uncertainty about such standard deviation has the effect of making the small probabilities rise. For instance, for a deviation that is called "three sigma," events that should take place no more than one in 740 observations, the probability rises by 60% if one moves the standard deviation up by 5%, and drops by 40% if we move the standard deviation down by 5%. So if your error is on average a tiny 5%, the underestimation from a naive model is about 20%. Great asymmetry, but nothing yet. It gets worse as one looks for more deviations, the "six sigma" ones (alas, chronically frequent in economics): a rise of five times more. The rarer the event (i.e., the higher the "sigma"), the worse the effect from small uncertainty about what to put in the equation. With events such as ten sigma, the difference is more than a billion times. We can use the argument to show how smaller and smaller probabilities require more precision in computation. The smaller the probability, the more a small, very small rounding in the computation makes the asymmetry massively insignificant. For tiny, very small probabilities, you need near-infinite precision in the parameters; the slightest uncertainty there causes mayhem. They are very convex to perturbations. This in a way is the argument

I've used to show that small probabilities are incomputable, even if one has the right model—which we of course don't.

The same argument relates to deriving probabilities nonparametrically, from past frequencies. If the probability gets close to 1/ sample size, the error explodes.

This of course explains the error of Fukushima. Similar to Fannie Mae. To summarize, small probabilities increase in an accelerated manner as one changes the parameter that enters their computation.

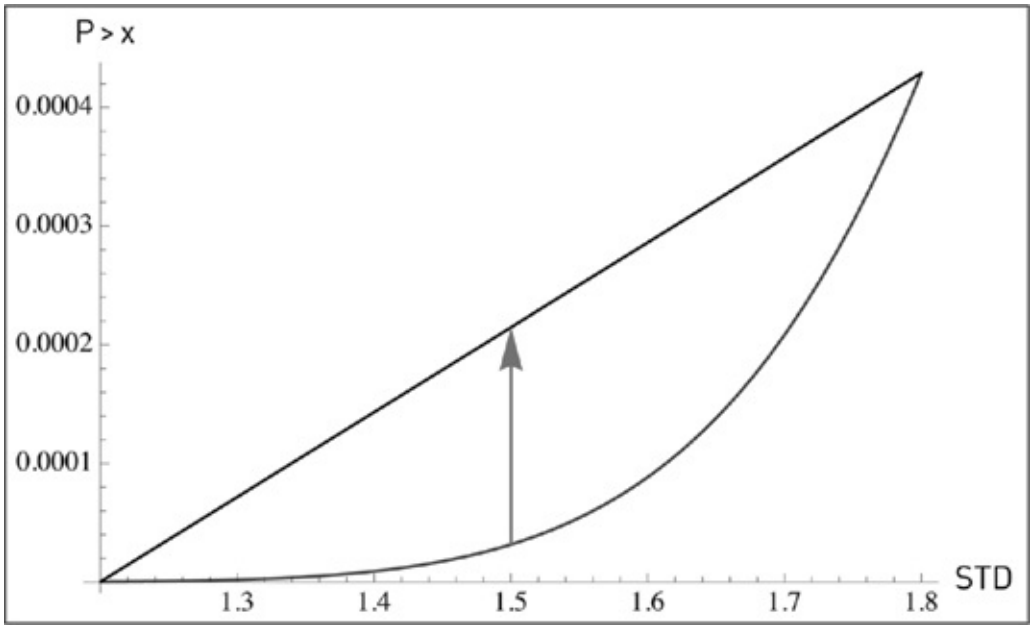

FIGURE 38. *The probability is convex to standard deviation in a Gaussian model. The plot shows the STD effect on P>x, and compares P>6 with an STD of 1.5 compared to P>6 assuming a linear combination of 1.2 and 1.8 (here a(1)=1/5).*

The worrisome fact is that a perturbation in σ extends well into the tail of the distribution in a convex way; the risks of a portfolio that is sensitive to the tails would explode. That is, we are still here in the Gaussian world! Such explosive uncertainty isn't the result of natural fat tails in the distribution, merely small imprecision about a future parameter. It is just epistemic! So those who use these models while admitting parameters uncertainty are necessarily committing a severe inconsistency.[2]

Of course, uncertainty explodes even more when we replicate conditions of the non-Gaussian real world upon perturbating tail exponents. Even with a powerlaw distribution, the results are severe, particularly under variations of the tail exponent as these have massive consequences. Really, fat tails mean

incomputability of tail events, little else.

Compounding Uncertainty (Fukushima)

Using the earlier statement that *estimation implies error*, let us extend the logic: errors have errors; these in turn have errors. Taking into account the effect makes all small probabilities rise regardless of model—even in the Gaussian—to the point of reaching fat tails and powerlaw effects (even the so-called infinite variance) when higher orders of uncertainty are large. Even taking a Gaussian with σ the standard deviation having a proportional error $a(1)$; $a(1)$ has an error rate $a(2)$, *etc*. Now it depends on the higher order error rate $a(n)$ related to $a(n-1)$; if these are in constant proportion, then we converge to a very thick-tailed distribution. If proportional errors decline, we still have fat tails. In all cases mere error is not a good thing for small probability.

The sad part is that getting people to accept that every measure has an error has been nearly impossible—the event in Fukushima held to happen once per million years would turn into one per 30 if one percolates the different layers of uncertainty in the adequate manner.

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[1] The difference between the two sides of Jensen's inequality corresponds to a notion in information theory, the Bregman divergence. Briys, Magdalou, and Nock, 2012.

[2] This further shows the defects of the notion of "Knightian uncertainty," since *all tails* are uncertain under the slightest perturbation and their effect is severe in fat-tailed domains, that is, economic life.

To Sarah Josephine Taleb

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ADDITIONAL NOTES, AFTERTHOUGHTS, AND FURTHER READING

These are both additional readings and ideas that came to me after the composition of the book, like whether God is considered robust or antifragile by theologians or the history of measurement as a sucker problem in the probability domain. As to further reading, I am avoiding the duplication of those mentioned in earlier books, particularly those concerning the philosophical problem of induction, Black Swan problems, and the psychology of uncertainty. I managed to bury some mathematical material in the text without Alexis K., the math-phobic London editor, catching me (particularly my definition of fragility in the notes for Book V and my summary derivation of "small is beautiful"). Note that there are more involved technical discussions on the Web.

Seclusion: Since *The Black Swan*, I've spent 1,150 days in physical seclusion, a soothing state of more than three hundred days a year with minimal contact with the outside world—plus twenty years of thinking about the problem of nonlinearities and nonlinear exposures. So I've sort of lost patience with institutional and cosmetic knowledge. Science and knowledge are convincing and deepened rigorous argument taken to its conclusion, not naive (*via positiva*) empiricism or fluff, which is why I refuse the commoditized (and highly gamed) journalistic idea of "reference"—rather, "further reading." My results should not depend, and do not depend on a single paper or result, except for *via negativa* debunking—these are illustrative.

Charlatans: In the "fourth quadrant" paper published in *International Journal of Forecasting* (one of the backup documents for *The Black Swan* that had been sitting on the Web) I showed *empirically* using all economic data available that fat tails are both severe and intractable—hence all methods with "squares" don't work with socioeconomic variables: regression, standard

deviation, correlation, *etc.* (technically 80% of the Kurtosis in 10,000 pieces of data can come from *one single* observation, meaning all measures of fat tails are just sampling errors). This is a very strong *via negativa* statement: it means we can't use covariance matrices—they are unreliable and uninformative. Actually just accepting fat tails would have led us to such result—no need for empiricism; I processed the data nevertheless. Now any honest scientific profession would say: "what do we do with such evidence?"—the economics and finance establishment just ignored it. A bunch of charlatans, by any scientific norm and ethical metric. Many "Nobels" (Engle, Merton, Scholes, Markowitz, Miller, Samuelson, Sharpe, and a few more) have their results grounded in such central assumptions, and all their works would evaporate otherwise. Charlatans (and fragilistas) do well in institutions. It is a matter of ethics; see notes on Book VII.

For our purpose here, I ignore any economic paper that uses regression in fat-tailed domains—as just hot air—except in some cases, such as Pritchet (2001), where the result is not impacted by fat tails.

PROLOGUE & BOOK I: The Antifragile: An Introduction

Wind energizes fire: Resembles La Rochefoucauld's comment on love.

Antifragility and complexity: Bar-Yam and Epstein (2004) define sensitivity, the possibility of large response to small stimuli, and robustness, the possibility of small response to large stimuli. In fact this sensitivity, when the response is positive, resembles antifragility.

Private Correspondence with Bar-Yam: Yaneer Bar-Yam, generously in his comments: "If we take a step back and more generally consider the issue of partitioned versus connected systems, partitioned systems are more stable, and connected systems are both more vulnerable and have more opportunities for collective action. Vulnerability (fragility) is connectivity without responsiveness. Responsiveness enables connectivity to lead to opportunity. If collective action can be employed to address threats, or to take advantage of opportunities, then the vulnerability can be mitigated and outweighed by the benefits. This is the basic relationship between the idea of sensitivity as we described it and your concept of antifragility." (With permission.)

Damocles and complexification: Tainter (1988) argues that sophistication leads to fragility—but following a very different line of reasoning.

Post-Traumatic Growth: Bonanno (2004), Tedeschi and Calhoun (1996), Calhoun and Tedeschi (2006), Alter *et al.* (2007), Shah *et al.* (2007), Pat-Horenczyk and Brom (2007).

Pilots abdicate responsibility to the system: FAA report: John Lowy, AP, Aug. 29, 2011.

Lucretius Effect: Fourth Quadran**t** discussion in the Postscript of *The Black Swan* and empirical evidence in associated papers.

High-water mark: Kahneman (2011), using as backup the works of the very insightful Howard Kunreuther, that "protective actions, whether by individuals or by governments, are usually designed to be adequate to the worst disaster actually experienced.… Images of even worse disaster do not come easily to mind."

Psychologists and "resilience": Seery 2011, courtesy Peter Bevelin. "However,

some theory and empirical evidence suggest that the experience of facing difficulties can also promote benefits in the form of greater propensity for resilience when dealing with subsequent stressful situations." They use resilience! Once again *itsnotresilience*.

Danchin's paper: Danchin *et al.* (2011).

Engineering errors and sequential effect on safety: Petroski (2006).

Noise and effort: Mehta *et al.* (2012).

Effort and fluency: Shan and Oppenheimer (2007), Alter *et al.* (2007).

Barricades: Idea communicated by Saifedean Ammous.

Buzzati: *Una felice sintesi di quell'ultimo capitolo della vita di Buzzati è contenuto nel libro di Lucia Bellaspiga «Dio che non esisti, ti prego. Dino Buzzati, la fatica di credere»*

Self-knowledge: Daniel Wegner's illusion of conscious will, in *Fooled by Randomness*.

Book sales and bad reviews: For Ayn Rand: Michael Shermer, "The Unlikeliest Cult in History," *Skeptic* vol. 2, no. 2, 1993, pp. 74–81. This is an example; please do not mistake this author for a fan of Ayn Rand.

Smear campaigns: Note that the German philosopher Brentano waged an anonymous attack on Marx. Initially it was the accusation of covering up some sub-minor fact completely irrelevant to the ideas of *Das Kapital;* Brentano got the discussion completely diverted away from the central theme, even posthumously, with Engels vigorously continuing the debate defending Marx in the preface of the third volume of the treatise.

How to run a smear campaign from Louis XIV to Napoleon: Darnton (2010).

Wolff's law and bones, exercise, bone mineral density in swimmers: Wolff (1892), Carbuhn (2010), Guadaluppe-Grau (2009), Hallström *et al.* (2010), Mudd (2007), Velez (2008).

Aesthetics of disorder: Arnheim (1971).

Nanocomposites: Carey *et al.* (2011).

Karsenty and Bones: I thank Jacques Merab for discussion and introduction to Karsenty; Karsenty (2003, 2012a), Fukumoto and Martin (2009); for male fertility and bones, Karsenty (2011, 2012b).

Mistaking the Economy for a Clock: A typical, infuriating error in Grant

(2001): “Society is conceived as a huge and intricate clockwork that functions automatically and predictably once it has been set in motion. The whole system is governed by mechanical laws that organize the relations of each part. Just as Newton discovered the laws of gravity that govern motion in the natural world, Adam Smith discovered the laws of supply and demand that govern the motion of the economy. Smith used the metaphor of the watch and the machine in describing social systems.”

Selfish gene: The “selfish gene” is (convincingly) an idea of Robert Trivers often attributed to Richard Dawkins—private communication with Robert Trivers. A sad story.

Danchin’s systemic antifragility and redefinition of hormesis: Danchin and I wrote our papers in feedback mode. Danchin *et al.* (2011): “The idea behind is that in the fate of a collection of entities, exposed to serious challenges, it may be possible to obtain a positive overall outcome. Within the collection, one of the entities would fare extremely well, compensating for the collapse of all the others and even doing much better than the bulk if unchallenged. With this view, hormesis is just a holistic description of underlying scenarios acting at the level of a population of processes, structures or molecules, just noting the positive outcome for the whole. For living organisms this could act at the level of the population of organisms, the population of cells, or the population of intracellular molecules. We explore here how antifragility could operate at the latter level, noting that its implementation has features highly reminiscent of what we name natural selection. In particular, if antifragility is a built-in process that permits some individual entities to stand out from the bulk in a challenging situation, thereby improving the fate of the whole, it would illustrate the implementation of a process that gathers and utilises information.”

Steve Jobs: “Death is the most wonderful invention of life. It purges the system of these old models that are obsolete.” Beahm (2011).

Swiss cuckoo clock: Orson Welles, *The Third Man.*

Bruno Leoni: I thank Alberto Mingardi for making me aware of the idea of legal robustness—and for the privilege of being invited to give the Leoni lecture in Milan in 2009. Leoni (1957, 1991).

Great Moderation: A turkey problem. Before the turmoil that started in 2008, a gentleman called Benjamin Bernanke, then a Princeton professor, later to be chairman of the Federal Reserve Bank of the United States and the most

powerful person in the world of economics and finance, dubbed the period we witnessed the "great moderation"—putting me in a very difficult position to argue for increase of fragility. This is like pronouncing that someone who has just spent a decade in a sterilized room is in "great health"—when he is the most vulnerable.

Note that the turkey problem is an evolution of Russell's chicken (*The Black Swan*).

Rousseau: In *Contrat Social*. See also Joseph de Maistre, *Oeuvres*, Éditions Robert Laffont.

BOOK II: Modernity and the Denial of Antifragility

City-states: Great arguments in support of the movement toward semiautonomous cities. Benjamin Barber, Long Now Foundation Lecture (2012), Khanna (2010), Glaeser (2011). Mayors are better than presidents at dealing with trash collection—and less likely to drag us into war. Also Mansel (2012) for the Levant.

Austro-Hungarian Empire: Fejtö (1989). Counterfactual history: Fejtö holds that the first war would have been avoided.

Random search and oil exploration: Menard and Sharman (1976), controversy White *et al.* (1976), Singer *et al.* (1981).

Randomizing politicians: Pluchino *et al.* (2011).

Switzerland: Exposition in Fossedal and Berkeley (2005).

Modern State: Scott (1998) provides a critique of the high modernistic state.

Levantine economies: Mansel (2012) on city-states. Economic history, Pamuk (2006), Issawi (1966, 1988), von Heyd (1886). Insights in Edmond About (About, 1855).

City-States in history: Stasavage (2012) is critical of the oligarchic city-state as an engine of long-term growth (though initially high growth rate). However, the paper is totally unconvincing econometrically owing to missing fat tails. The issue is fragility and risk management, not cosmetic growth. Aside from Weber and Pirenne, advocates of the model, Delong and Schleifer (1993). See Ogilvie (2011).

Tonsillectomies: Bakwin (1945), cited by Bornstein and Emler (2001), discussion in Freidson (1970). Redone by Avanian and Berwick (1991).

Orlov: Orlov (2011).

Naive interventionism in development: Easterly (2006) reports a green lumber problem: “The fallacy is to assume that because I have studied and lived in a society that somehow wound up with prosperity and peace, I know enough to plan for other societies to have prosperity and peace. As my friend April once said, this is like thinking the racehorses can be put in charge of building the racetracks.”

Also luck in development, Easterly *et al.* (1993), Easterly and Levine

(2003), Easterly (2001).

China famine: Meng *et al.* (2010).

Washington's death: Morens (1999); Wallenborn (1997).

Koran and Iatrogenics:

واذا قيل لهم لا تفسدوا في الأرض قالوا انما نحن مصلحون. الا انهم هم المفسدون ولكن لا يعلمون

وإذا قيل لهم امنوا كما امن الناس قالوا أنؤمن كما امن السفهاء ألا إنهم هم السفهاء ولكن لا يعلمون

Semmelweiss: Of the most unlikely references, see Louis-Ferdinand Céline's doctoral thesis, reprinted in Gallimard (1999), courtesy Gloria Origgi.

Fake stabilization: Some of the arguments in Chapter 7 were co-developed with Mark Blyth in *Foreign Affairs*, Taleb and Blyth (2011).

Sweden: "Economic elites had more autonomy than in any successful democracy," Steinmo (2011).

Traffic and removal of signs: Vanderbilt (2008).

History of China: Eberhard (reprint, 2006).

Nudge: They call it the *status quo bias* and some people want to get the government to manipulate people into breaking out of it. Good idea, except when the "expert" nudging us is not an expert.

Procrastination and the priority heuristic: Brandstetter and Gigerenzer (2006).

France's variety: Robb (2007). French riots as a national sport, Nicolas (2008). Nation-state in France, between 1680 and 1800, Bell (2001).

Complexity: We are more interested here in the effect on fat tails than other attributes. See Kaufman (1995), Hilland (1995), Bar-Yam (2001), Miller and Page (2007), Sornette (2004).

Complexity and fat tails: There is no need to load the math here (left to the technical companion); simple rigorous arguments can prove with minimal words how fat tails emerge from some attributes of complex systems. The important mathematical effect comes from lack of independence of random variables which prevents convergence to the Gaussian basin.

Let us examine the effect from dynamic hedging and portfolio revisions.

A—Why fat tails emerge from leverage and feedback loops, single agent simplified case.

A1 [leverage]—If an agent with some leverage L buys securities in

response to increase in his wealth (from the increase of the value of these securities held), and sells them in response to decrease in their value, in an attempt to maintain a certain level of leverage L (he is concave in exposure), and

A2 [feedback effects]—If securities rise nonlinearly in value in response to purchasers and decline in value in response to sales, then, by the violation of the independence between the variations of securities, CLT (the central limit theorem) no longer holds (no convergence to the Gaussian basin). So fat tails are an immediate result of feedback and leverage, exacerbated by the concavity from the level of leverage L.

A3—If feedback effects are concave to size (it costs more per unit to sell 10 than to sell 1), then negative skewness of the security and the wealth process will emerge. (Simply, like the "negative gamma" of portfolio insurance, the agent has an option in buying, but no option in selling, hence negative skewness. The forced selling is exactly like the hedging of a short option.)

Note on path dependence exacerbating skewness: More specifically, if wealth increases first, this causes more risk and skew. Squeezes and forced selling on the way down: the market drops more (but less frequently) than it rises on the way up.

B—Multiagents: if, furthermore, more than one agent is involved, then the effect is compounded by the dynamic adjustment (hedging) of one agent causing the adjustment of another, something commonly called "contagion."

C—One can generalize to anything, such as home prices rising in response to home purchases from excess liquidity, *etc.*

The same general idea of forced execution plus concavity of costs leads to the superiority of systems with distributed randomness.

Increase of risk upon being provided numbers: See the literature on anchoring (reviewed in *The Black Swan*). Also Mary Kate Stimmler's doctoral thesis at Berkeley (2012), courtesy Phil Tetlock.

Stimmler's experiment is as follows. In the simple condition, subjects were told:

For your reference, you have been provided with the following formula for calculating the total amount of money (*T*) the investment will make three months after the initial investment (*I*) given the rate of return (*R*):

$$T=I*R$$

In the complex condition, subjects were told:

For your reference, you have been provided with the following formula for calculating the total amount of money A_n the investment will make three months after the initial investment A_{n-1} given the rate of return *r*.

$$A_n = A_{n-1} + (n+1)\sum_{j=1}^{n-1}[A_j r_j \frac{j}{n^2-n+j} - jA_{j-1}r_{j-1} \frac{1}{j+(n-1)^2+n-2} + A_j r_{j-1}\frac{1}{j+(n-1)^2+n-2}]$$

Needless to mention that the simple condition and the complex one produced the same output. But those who had the complex condition took more risks.

The delusion of probabilistic measurement: Something that is obvious to cabdrivers and grandmothers disappears inside university hallways. In his book *The Measure of Reality* (Crosby, 1997), the historian Alfred Crosby presented the following thesis: what distinguished Western Europe from the rest of the world is obsession with measurement, the transformation of the qualitative into the quantitative. (This is not strictly true, the ancients were also obsessed with measurements, but they did not have the Arabic numerals to do proper calculations.) His idea was that we learned to be precise about things—and that was the precursor of the scientific revolution. He cites the first mechanical clock (which quantized time), marine charts and perspective painting (which quantized space), and double-entry bookkeeping (which quantized financial accounts). The obsession with measurement started with the right places, and progressively invaded the wrong ones.

Now our problem is that such measurement started to be applied to elements that have a high measurement error—in some case infinitely high. (Recall Fukushima in the previous section.) Errors from Mediocristan are inconsequential, those from Extremistan are acute. When measurement errors

are prohibitively large, we should not be using the word "measure." Clearly I can "measure" the table on which I am writing these lines. I can "measure" the temperature. But I cannot "measure" future risks. Nor can I "measure" probability—unlike this table it cannot lend itself to our investigation. This is at best a speculative estimation of something that *can* happen.

Note that Hacking (2006) does not for a single second consider fat tails! Same with Hald (1998, 2003), von Plato (1994), Salsburg (2001), and from one who should know better, Stigler (1990). A book that promoted bad risk models, Bernstein (1996). Daston (1988) links probabilistic measurement to the Enlightenment.

The idea of probability as a quantitative not a qualitative construct has indeed been plaguing us. And the notion that science *equals* measurement free of error—it is, largely but not in everything—can lead us to all manner of fictions, delusions, and dreams.

An excellent understanding of probability linked to skepticism: Franklin (2001). Few other philosophers go back to the real problem of probability.

Fourth Quadrant: See the discussion in *The Black Swan* or paper Taleb (1999).

Nuclear, new risk management: Private communication, Atlanta, INPO, Nov. 2011.

Anecdotal knowledge and power of evidence: A reader, Karl Schluze, wrote: "An old teacher and colleague told me (between his sips of bourbon) 'If you cut off the head of a dog and it barks, you don't have to repeat the experiment.' " Easy to get examples: no lawyer would invoke an "N=1" argument in defense of a person, saying "he only killed once"; nobody considers a plane crash as "anecdotal."

I would go further and map disconfirmation as exactly where N=1 is sufficient.

Sometimes researchers call a result "anecdotal" as a knee-jerk reaction when the result is exactly the reverse. Steven Pinker called John Gray's pointing out the two world wars as counterevidence to his story of great moderation "anecdotal." My experience is that social science people rarely know what they are talking about when they talk about "evidence."

BOOK III: A Nonpredictive View of the World

Decision theorists teaching practitioners: To add more insults to us, decision scientists use the notion of "practical," an inverse designation. See Hammond, Keeney, and Raiffa (1999) trying to teach us how to make decisions. For a book describing exactly how practitioners don't act, but how academics think practitioners act: Schon (1983).

The asymmetry between good and bad: *Segnius homines bona quam mala sentiunt* in Livy's *Annals* (XXX, 21).

Stoics and emotions: Contradicts common beliefs that Stoicism is about being a vegetable, Graver (2007).

Economic growth was not so fast: Crafts (1985), Crafts and Harley (1992).

Cheating with the rock star: Arnavist and Kirkpatrick (2005), Griffith *et al.* (2002), Townsend *et al.* (2010).

Simenon: "Georges Simenon, profession: rentier," Nicole de Jassy *Le Soir illustré* 9 janvier 1958, N° 1333, pp. 8–9, 12.

Dalio: Bridgewater-Associates-Ray-Dalio-Principles.

BOOK IV: Optionality, Technology, and the Intelligence of Antifragility

The Teleological

Aristotle and his influence: Rashed (2007), both an Arabist and a Hellenist.

The nobility of failure: Morris (1975).

Optionality

Bricolage: Jacob (1977a, 1977b), Esnault (2001).

Rich getting richer: On the total wealth for HNWI (High Net Worth Individuals) increasing, see Merrill Lynch data in "World's wealthiest people now richer than before the credit crunch," Jill Treanor, *The Guardian,* June 2012. The next graph shows why it has nothing to do with growth and total wealth formation.

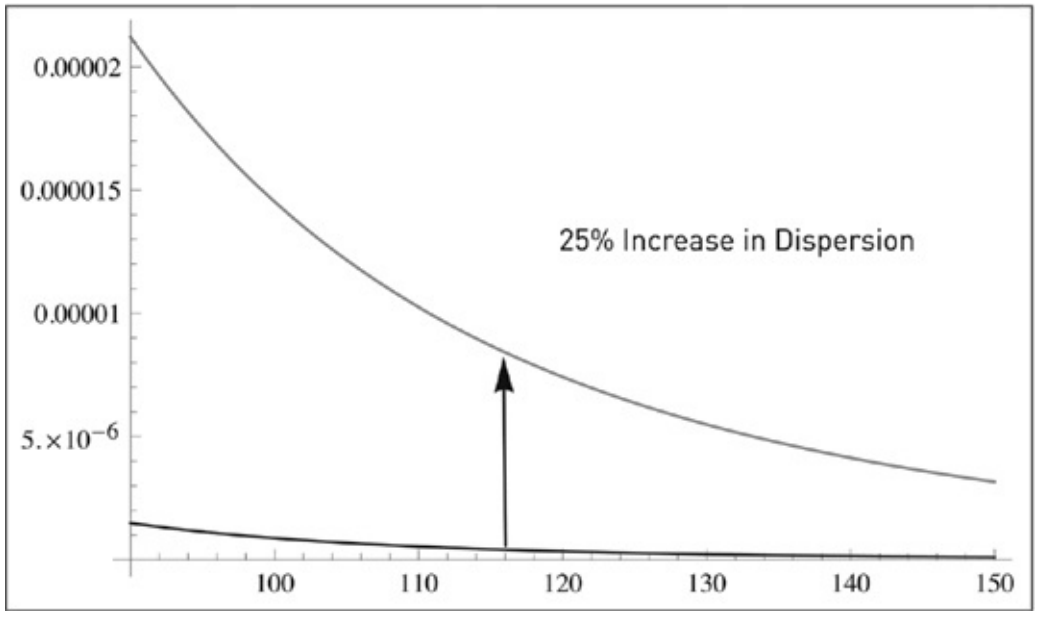

FIGURE 39. *Luxury goods and optionality. On the vertical the probability, on the horizontal the integral of wealth. Antifragility city: the effect of change in inequality on the pool of very rich increases nonlinearly in the tails: the money of the superrich reacts to inequality rather than total wealth in the world. Their share of wealth multiplies by close to 50 times in response to a change of 25% in dispersion of wealth. A small change of 0.01 in the GINI coefficient (0 when perfect inequality, 1.00 when one person has all) equivalent to 8% rise in real Gross Domestic Product—the effect is stark regardless of the probability distribution.*

Camel in Arabia: Lindsay (2005).

Obliquity: Kay (2010).

Real options literature: Trigeorgis (1993), review in Dixit and Pindyck (1994), Trigeorgis (1996), Luehrman (1998), McGrath (1999)—the focus is on reversible and irreversible investments.

Translational gap: Wooton (2007); Arikha (2008b); modern Contopoulos-Ioannidis *et al.* (2003, 2008), commentary Bosco and Watts (2007).

Criticism of Wootton: Brosco and Watts (2007).

Epiphenomena and Granger-causality: See Granger (1999) for a review.

Lecturing birds how to fly: There are antecedents in Erasmus, "teaching fish how to swim." *Adages,* 2519, III, VI, 19. "*Piscem nature doces* Ι'χθὺν νήχεσθαι διδάσκεις, *id est piscem nature doces. Perinde est ac si dicas : Doctum doces. Confine illi, quod alibi retulimus :* Δελφῖνα νήχεσθαι διδάσκεις, *id est Delphinum natare doces."* The expression was first coined in Haug and Taleb (2010), posted in 2006, leading to a book, Triana (2009). We weren't aware of the Erasmus imagery, which we would have selected instead.

Education and its effect on growth and wealth: Pritchett (2001), Wolf (2002), Chang (2011).

Schumpeter's ideas on destruction for advancement: Schumpeter (1942). Criticism by Harvard economists about lack of technical approach in McCraw (2007).

Amateurs: Bryson (2010), Kealey (1996).

Scientific misattribution of the works of Bachelier, Thorpe, and others: Haug and Taleb (2010). Discussion in Triana (2009, 2011).

Ex cura theoria nascitur: In Coulter (2000), attributed to Paracelsus.

Jet engine: Scranton (2006, 2007, 2009), Gibbert and Scranton (2009).

Busting the episteme theory of cybernetics: Mindell, 2002. I thank David Edgerton for introducing me to his works.

Cathedrals and theoretical and axiomatic geometry: Beaujoan (1973, 1991), Portet (2002). Ball (2008) for the history of the construction of Chartres cathedral.

Epistemic base and conflation: The epistemic base is sort of the x, not $f(x)$. A

great way to see the difference between x and $f(x)$ in technology, offered by Michael Polanyi: one can patent $f(x)$, a technique, but not x, scientific knowledge. In Mokyr (2005).

Epistemic Base: Mokyr (1999, 2002, 2005, 2009). The biggest problem with Mokyr: not getting ω_C. Further, this notion of the East missing trial and error (also see argument about China): see Tetlock in Tetlock *et al.* (2009). Mokyr and Meisenzahl have a different spin, with microinventions feeding macroinventions. Still intellectually weak.

Techne-Episteme in economics: Marglin (1996), but the tradition did not go very far.

Needham's works on China: Winchester (2008).

Tenure: Kealey (1996): "Adam Smith attributed the English professors' decay to their guaranteed salaries and tenured jobs. (As compared to Scottish Universities.)"

Fideism: Popkin (2003).

Linear Model: Edgerton (1996a, 1996b, 2004). Edgerton showed that it was a backward-fit idea, that is, fit to the past. Edgerton also writes: "This profoundly academic-research-oriented model of twentieth-century science is all the more surprising in view of the long tradition of *stressing the non-academic origins of modern science* [emphasis mine], particularly the craft traditions, and the insistence of much history of science, strengthened in the last 20 years, on the significance of industrial contexts for science, from dyeing to brewing to engine making."

Convexity bias: It was discovered early in commodity and financial futures; Burghardt and Hoskins (1994), Taleb (1997), Burghardt and Liu (2002), Burghardt and Panos (2001), Kirikos and Novak (1997), Pieterbarg and Renedo (2004). Many people blew up on misunderstanding the effect.

Example of detection and mapping of convexity bias (ω_A), from author's doctoral thesis: The method is to find what needs dynamic hedging and dynamic revisions. Among the members of the class of instruments considered that are not options *stricto-sensu* but require dynamic hedging can be rapidly mentioned a broad class of convex instruments: (1) Low coupon long dated bonds. Assume a discrete time framework. Take $B(r,T,C)$ the bond maturing period T, paying a coupon C where $rt = \int rs\, ds$. We have the convexity $\partial^2 B/\partial r^2$ increasing with T and decreasing with C. (2) Contracts

where the financing is extremely correlated with the price of the Future. (3) Baskets with a geometric feature in its computation. (4) A largely neglected class of assets is the "quanto-defined" contracts (in which the payoff is not in the native currency of the contract), such as the Japanese NIKEI Future where the payoff is in U.S. currency. In short, while a Japanese yen denominated NIKEI contract is linear, a U.S. dollars denominated one is nonlinear and requires dynamic hedging.

Take at initial time t_0, the final condition $V(S,T) = S_T$ where T is the expiration date. More simply, the security just described is a plain forward, assumed to be linear. There appears to be no Ito term there yet. However should there be an intermediate payoff such that, having an accounting period i/T, the variation margin is paid in cash disbursement, some complexity would arise. Assume $\Delta(t_i)$ the changes in the value of the portfolio during period (t_i,t_{i-1}), $\Delta(t_i)= (V(S,t_i)-V(S, t_{i-1}))$. If the variation is to be paid at period t_i, then the operator would have to borrow at the forward rate between periods t_i and T, here $r(t_i,T)$. This financing is necessary to make $V(S,T)$ and S_T comparable in present value. In expectation, we will have to discount the variation using forward cash flow method for the accounting period between t_{i-1} and t_i. Seen from period T, the value of the variation becomes $E_t\,[exp[-r(t_i,T)(T-t_i)]\,\Delta(t_i)]$, where E_t is the expectation operator at time t (under, say, the risk-neutral probability measure). Therefore we are delivering at period T, in expectation, as seen from period t_0, the expected value of a stream of future variation $E_{t0}[\Sigma\, exp[-r(t_i,T)(T-t_i)]\,\Delta(t_i)]$. However we need to discount to the present using the term rate $r(T)$. The previous equation becomes $V(S,T)|_{t=t0}= V[S,t_0]+ exp[r(T)]\, E_{to}\,[\Sigma\, exp[-r(t_i,T)(T-t_i)]\,\Delta(t_i)]$, which will be different from S_T when any of the interest rate forwards is stochastic. **Result** (a polite way to say "theorem"): *When the variances of the forward discount rate $r(t_i,T)$ and the underlying security S_T are strictly positive and the correlation between the two is lower than 1, $V(S,T)|_{t=t0} \neq S_T$.* Proof: by examining the properties of the expectation operator. Therefore: $F(S, t_0) = F(S,t_0+\Delta t)$, while a nonlinear instrument will merely satisfy: $E[V(S,t_0)]=E[V(S,t_0+\Delta t)]$.

Critique of Kealey: Posner (1996).

General History of Technology: Missing convexity biases, Basalla (1988), Stokes (1997), Geison (1995).

Ideas of innovation: Berkun (2007), Latour and Woolfar (1996), Khosla (2009), Johnson (2010).

Medical discoveries and absence of causative knowledge: Morton (2007), Li (2006), Le Fanu (2002), Bohuon and Monneret (2009). Le Fanu (2002): "It is perhaps predictable that doctors and scientists should assume the credit for the ascendency of modern medicine without acknowledging, or indeed recognizing, the mysteries of nature that have played so important a part. Not surprisingly, they came to believe their intellectual contribution to be greater than it really was, and that they understood more than they really did. They failed to acknowledge the overwhelmingly empirical nature of technological and drug innovation, which made possible spectacular breakthroughs in the treatment of disease without the requirement of any profound understanding of its causation or natural history."

Commerce as convex: Ridley (2010) has comments on Phoenicians; Aubet (2001).

Pharma's insider: La Matina (2009).

Multiplicative side effects: Underestimation of interactions in Tatonetti *et al.* (2012): they simply uncovered the side effects of people taking joint drugs together, which effectively swells the side effects (they show something as large as a multiplication of the effect by 4).

Strategic planning: Starbuck *et al.* (1992, 2008), Abrahamson and Freedman (2007). The latter is a beautiful ode to disorder and "mess."

Entrepreneurship: Elkington and Hartigan (2008).

Harvard Business School professors' pathological misunderstanding of small probabilities: This is not an empirical statement, but just to have fun: for an illustrative example of a sucker who misses ω_B and ω_C, always start looking in Harvard. Froot (2001), Pisano (2006a, 2006b). Froot: "Because managers of insurance companies purchase reinsurance at far above the fair price, they must believe that risk management adds considerable value." He thinks *he* knows the fair price.

Le Goff: Le Goff (1985): *"L'un est un professeur, saisi dans son enseignement, entouré d'élèves, assiégé par les bans, où se presse l'auditoire. L'autre est un savant solitaire, dans son cabinet tranquille, à l'aise au milieu de la pièce où se meuvent librement ses pensées. Ici c'est le tumulte des écoles, la poussière des salles, l'indifférence au décor du labeur collectif," "Là tout n'est*

qu'ordre et beauté / Luxe, calme, et volupté."

Martignon: *Geschlechtsspezifische Unterschiede im Gehirn und mögliche Auswirkungen auf den Mathematikunterricht.* Wissenschaftliche Hausarbeit zur Ersten Staatsprüfung für das Lehramt an Realschulen nach der RPO I v. 16.12.1999. Vorgelegt von: Ulmer, Birgit. Erste Staatsprüfung im Anschluss an das Wintersemester 2004/05, Pädagogische Hochschule Ludwigsburg. Studienfach: Mathematik. Dozenten: Prof. Dr. Laura Martignon, Prof. Dr. Otto Ungerer.

Renan: *Averroès et l'averroïsme*, p. 323 (1852).

Socrates: Conversation with Mark Vernon (Vernon, 2009), who believes that Socrates was more like Fat Tony. Wakefield (2009) a great context. Calder *et al.* (2002) presents portraits more or less hagiographic.

Socratic Fallacy: Geach (1966).

Episteme-Techne*:* Alexander of Aphrodisias, *On Aristotle's Metaphysics*, *On Aristotle's Prior Analytics* 1.1–7, *On Aristotle's Topics* 1, *Quaestiones* 2.16–3.15.

Tacit-Explicit knowledge: Colins (2010), Polanyi (1958), Mitchell (2006).

Click here for a larger image of this table.

TABLE 13 • KNOW HOW VS KNOW WHAT AND THEIR SIBLINGS

TYPE 1	*TYPE 2*
Know *what*	Know *how*
Explicit	Implicit, Tacit
Demonstrative knowledge	Nondemonstrative knowledge
Episteme	Techne
Epistemic base	Experiential knowledge
Propositional knowledge	**Heuristic**
Literal	Figurative
Targeted activity	Bricolage
Rationalism	**Empiricism**

Scholarship	Practice
Mathematics	Engineering
Inductive knowledge, using Aristotle's teleological principles	Epilogism (Menodotus of Nicomedia and the school of empirical medicine)
Causative historiography	*Historia a sensate cognitio*
Diagnostic	*Autopsia*
Letter of the law	Spirit of the law
Ideas	Customs
Ludic probability, statistics textbooks	Ecological uncertainty, not tractable in textbook
Logos	Mythos
Kerygma (the explainable and teachable part of religion)	Dogma (in the religious sense, the unexplainable)
Exoteric theology (Averroes and Spinoza)	Esoteric theology (Averroes and Spinoza)

All the terms on the left seem to be connected. We can easily explain how *rationalism*, *explicit*, and *literal* fit together. But the terms on the right do not appear to be logically connected. What connects *customs*, *bricolage*, *myths*, *knowhow*, and *figurative*? What is the connection between religious dogma and tinkering? There is *something*, but I can't explain it in a compressed form, but there is the Wittgenstein family resemblance.

Lévi-Strauss: Lévi-Strauss (1962) on different forms of intelligence. However, in Charbonnier (2010), in interviews in the 1980s, he seems to believe that some day in the future, science will allow us to predict with acceptable precision very soon, "once we get the theory of things." Wilken (2010) for bio. See also Bourdieu (1972) for a similar problem seen from a sociologist.

Evolutionary heuristics: This is central but I hide it here. To summarize the view—a merger of what it is in the literature and the ideas of this book: an evolutionary heuristic in a given activity has the following attributes: (a) you don't know you are using it, (b) it has been done for a long time in the very same, or rather similar environment, by generations of practitioners, and reflects some evolutionary collective wisdom, (c) it is free of the agency

problem and those who use it survived (this excludes medical heuristics used by doctors since the patient might not have survived, and is in favor of collective heuristics used by society), (d) it replaces complex problems that require a mathematical solution, (e) you can only learn it by practicing and watching others, (f) you can always do "better" on a computer, as these do better on a computer than in real life. For some reason, these heuristics that are second best do better than those that seem to be best, (g) the field in which it was developed allows for rapid feedback, in the sense that those who make mistakes are penalized and don't stick around for too long. Finally, as the psychologists Kahneman and Tversky have shown, outside the domains in which they were formed, these can go awfully wrong.

Argumentation and the green lumber problem: In Mercier and Sperber (2011). The post-Socratic idea of reasoning as an instrument for seeking the truth has been recently devalued further—though it appears that the Socratic method of discussion might be beneficial, but only in a dialogue form. Mercier and Sperber have debunked the notion that we use reasoning in order to search for the truth. They showed in a remarkable study that the purpose of arguments is not to make decisions but to convince others—since decisions we arrive at by reasoning are fraught with massive distortions. They showed it experimentally, producing evidence that individuals are better at forging arguments in a social setting (when there are others to convince) than when they are alone.

Anti-Enlightenment: For a review, Sternhell (2010), McMahon (2001), Delon (1997). Horkheimer and Adorno provide a powerful critique of the cosmeticism and sucker-traps in the ideas of modernity. And of course the works of John Gray, particularly Gray (1998) and *Straw Dogs*, Gray (2002).

Wittgenstein and tacit knowledge: Pears (2006).

On Joseph de Maistre: Companion (2005).

Ecological, non-soccer-mom economics: Smith (2008), also Nobel lecture given along with Kahneman's. Gigerenzer further down.

Wisdom of the ages: Oakeshott (1962, 1975, 1991). Note that Oakeshott conservatism means accepting the necessity of a certain rate of change. It seems to me that what he wanted was organic, not rationalistic change.

BOOK V: The Nonlinear and the Nonlinear

More formally, to complement the graphical exposition, from Taleb and Douady (2012), the **local fragility** of a random variable $X\lambda$ depending on parameter λ, at stress level K and semi-deviation level $s^-(\lambda)$ with pdf f_λ is its **K-left-tailed semi-vega sensitivity** ("vega" being sensitivity to some measure of volatility), $V(X, f\lambda, K, s^-)$ to s^-, the mean absolute semi-deviation below Ω, here $s^-(\lambda) = \int_{-\infty}^{\Omega} (\Omega - x) f_\lambda(x) dx$, $\xi(K, s^-) = \int_{-\infty}^{K} (\Omega - x) f_{\lambda(s^-)}(x) dx$, $V(X, f_\lambda, K, s^-) = \frac{\partial \xi}{\partial s^-}(K, s^-)$. The **inherited fragility** of Y with respect to X at stress level $L = \varphi(K)$ and left-semi-deviation level $s^-(\lambda)$ of X is the partial derivative $V_x(Y, g_\lambda, L, s^-(\lambda)) = \frac{\partial \zeta}{\partial s}(L, u^-(\lambda))$. Note that the stress level and the pdf are defined for the variable Y, but the parameter used for differentiation is the left-semi-absolute deviation of X. For antifragility, the flip above Ω, in addition to robustness below the same stress level K. The **transfer theorems** relate the fragility of Y to the second derivative $\varphi(K)$ and show the effect of convex (concave or mixed nonlinear) transformations on the tails via the **transfer function** H^K. For the antifragile, use s^+, the integral above K.

Fragility is not psychological: We start from the definition of fragility as tail vega sensitivity and end up with nonlinearity as a necessary attribute of the source of such fragility in the inherited case—a cause of the disease rather than the disease itself. However, there is a long literature by economists and decision scientists embedding risk into psychological preferences—historically, risk has been described as derived from risk aversion as a result of the structure of choices under uncertainty with a concavity of the muddled concept of "utility" of payoff; see Pratt (1964), Arrow (1965), Rothschild and Stiglitz (1970, 1971). But this "utility" business never led anywhere except the circularity, expressed by Machina and Rothschild (2008), "risk is what risk-averters hate." Indeed limiting risk to aversion to concavity of choices is a quite unhappy result.

The porcelain cup and its concavity: Clearly, a coffee cup, a house, or a bridge doesn't have psychological preferences, subjective utility, *etc.* Yet each is

concave in its reaction to harm: simply, taking z as a stress level and $\Pi(z)$ the harm function, it suffices to see that, with $n>1$, $\Pi(n\,z) < n\,\Pi(z)$ for all $0< n\,z<Z^*$, where Z^* is the level (not necessarily specified) at which the item is broken. Such inequality leads to $\Pi(z)$ having a negative second derivative at the initial value z. So if a coffee cup is less harmed by n times a stressor of intensity Z than once a stressor of $n\,Z$, then harm (as a negative function) needs to be concave to stressors up to the point of breaking; such stricture is imposed by the structure of survival probabilities and the distribution of harmful events, nothing to do with subjective utility or some other figments.

Scaling in a positive way, convexity of cities: Bettencourt and West (2010, 2011), West (2011). Cities are 3-D items like animals, and these beneficial nonlinearities correspond to efficiencies. But consider traffic!

"More Is Different": Anderson (1972).

Comparative fragility of animals: Diamond (1988).

Flyvbjerg and colleagues on delays: Flyvbjerg (2009), Flyvbjerg and Buzier (2011).

Small Is Beautiful, the romantic views: Dahl and Tufte (1973), Schumacher (1973) for the soundbite. Kohr (1957) for the first manifesto against the size of the governing unit.

Size of government: I can't find people thinking in terms of convexity effects, not even libertarians—take Kahn (2011).

Small states do better: A long research tradition on governance of city-states. It looks like what we interpret as political systems might come from size. Evidence in Easterly and Kraay (2000).

The age of increasing fragility: Zajdenwebber, see the discussion in *The Black Swan*. Numbers redone recently in *The Economist,* "Counting the Cost of Calamities," Jan. 14, 2012.

Convexity effect on mean: Jensen (1906), Van Zwet (1966). While Jensen deals with monotone functions, Van Zwet deals with concave-convex and other mixtures—but these remain simple nonlinearities. Taleb and Douady (2012) applies it to all forms of local nonlinearities.

Empirical record of bigger: Mergers and hubris hypothesis: in Roll (1986); since then Cartwright and Schoenberg (2006).

Debt in ancient history: Babylonian jubilees, Hudson *et al.* (2002). Athens,

Harrison (1998), Finley (1953). History of debt, Barty-King (1997), Muldrew (1993), Glaeser (2001). The latter has an anarchist view. He actually believes that debt precedes barter exchange.

Food networks: Dunne *et al.* (2002), Perchey and Dunne (2012), Valdovinos and Ramos-Jiliberto (2010). Fragility and resources, Nasr (2008, 2009).

Fannie Mae: They were concave across all meaningful variables. Some probability-and-nonlinearity-challenged fellow in the Obama commission investigating the cause of the crisis spread the rumor that I only detected interest rate risk of Fannie Mae: not true.

Costs of execution: "Price impact," that is, execution costs, increase with size; they tend to follow the square root—meaning the total price is convex and grows at exponent 3/2 (meaning costs are concave). But the problem is that for large deviations, such as the Société Générale case, it is a lot worse; transaction costs accelerate, in a less and less precise manner—all these papers on price impact by the new research tradition are meaningless when you need them. Remarkably, Bent Flyvbjerg found a similar effect, but slightly less concave in total, for bridges and tunnels with proportional costs growing at 10 Log[x] of size.

Small Is Beautiful, a technical approach: To explain how city-states, small firms, *etc.* are more robust to harmful events, take X, a random variable for the "unintended exposure," the source of uncertainty (for Soc Gen it was the position that it did not see, for a corporation it might be an emergency need to some inventory, etc.). Assume the size of this unintended harm is proportional to the size of the unit—for smaller entities engage in smaller transactions than larger ones. We use for probability distribution the variable of all unintended exposures $\sum X_i$ where X_i are independent random variables, simply scaled as $X_i = X/N$. With k the tail amplitude and α the tail exponent, $\pi(k, \alpha, X) = \alpha\, k^{\alpha}\, x^{-1-\alpha}$. The N-convoluted Pareto distribution for the unintended total position $N \sum X_i$: $\pi(k/N, \alpha, X)_N$ where N is the number of convolutions for the distribution. The mean of the distribution, invariant with respect to N, is $\alpha\, k/\alpha{-}1$).

Losses from squeezes and overruns: for the loss function, take $C[X] = -b\, X^{\beta}$, where costs of harm is a concave function of X. Note that for small deviations, $\beta = 3/2$ in the microstructure and execution literature.

Resulting probability distribution of harm: As we are interested in the distribution of y, we make a transformation of stochastic variable. The harm

$y=C[X]$ has for distribution: $\pi[C^{-1}[x]]/C'[C^{-1}[x]]$. Consider that it follows a Pareto distribution with tail amplitude k^{β} and tail exponent α/β, $L_1(Y)=\frac{\alpha}{\beta}K^{\alpha}Y^{-1-\alpha/\beta}$ which has for mean $\frac{k^{\beta}\alpha}{\alpha-\beta}$. Now the sum: for the convoluted sum of N entities, the asymptotic distribution becomes:

$L_N(Y)=N\frac{\alpha}{\beta}\left(\frac{K}{N}\right)^{\alpha}Y^{-1-\alpha/\beta}$ with mean (owing to additivity) as a function of the variables which include N: $M(\alpha,\beta,k,N)=\frac{N\left(\frac{k}{N}\right)^{\beta}\alpha}{\alpha-\beta}$. If we check the ratio of expected losses in the tails for $N=1$ to $N=10$ at different values of the ratio of β over α, the ratio of the expectation for 1 unit over 10 units $\frac{M(\alpha=3,\beta/\alpha,k,N=1)}{M(\alpha=3,\beta/\alpha,k,N=10)}$ reveals the “small is beautiful” effect across different levels of concavity.

BOOK VI: Via Negativa

Subtractive Knowledge

Maps: A reader, Jean-Louis, a mapmaker, writes to me: "As a mapmaker, I learned a long time ago that the key to good mapmaking is precisely the info you choose to leave out. I have made numerous clients notice that if a map is too literal and precise, it confuses people."

Imam Ali: Nahj-el-Balagha, Letter. 31.

The mosaic god is not antifragile: For God—the Abrahamic-Mosaic God (of Jews, Christians, and Moslems)—is the representation of total robustness and infallibility. Note that counter to initial impressions, the essence of perfection is robustness, not antifragility. I've received many messages suggesting that the (Levantine) God should be put in the antifragile category. This would be a severe mistake according to Eastern Mediterranean religions. Antifragility for a deity may apply to Babylonian, Greek, Syrian, and Egyptian mythologies. But Levantine monotheistic theology, from the ancient Semitic El (or Al) to the modern Allah or, to a lesser extent, what people call "the Lord" in the Bible Belt, from Genesis to the Koran, progressed into a definition of an increasingly abstract God—hence closest to the definition of pure robustness. The monotheistic God is certainly not fragile; but he is not antifragile. By definition, thanks to his maximally abstract quality, he is what cannot be improved, which is the very property of perfection—only imperfect mortals can improve, therefore need antifragility to try to improve. In the Koran, one of the properties of God is *Smd*, a word that has no synonym even in Arabic, hence cannot be translated; its meaning can only be conveyed through the iteration of partial descriptions. *Smd* is that which has reached such degree of completeness that it does not depend on external circumstances, anything or anyone; a bulwark against all manner of attacks; He transcends the notion of time. The idea is also present in other Levantine systems. Orthodox theology, through *theosis,* seeks merger with God, the aspiration to a level of completeness, hence independence from anything else.

Interdicts in religion: Fourest and Venner (2010) presents a list across all persuasions.

Steve Jobs: Beahm (2011).

Gladwell: "If you totted up all his hospital bills for the ten years that he had been on the streets—as well as substance-abuse-treatment costs, doctors' fees, and other expenses—Murray Barr probably ran up a medical bill as large as anyone in the state of Nevada. 'It cost us one million dollars not to do something about Murray,' O'Bryan said." Gladwell (2009).

Falsification and problems of induction: See references in *The Black Swan*.

Smoking and overall medical effect: Burch (2009).

Fractality: Mandelbrot (1983).

Edgerton's shock of the old: Edgerton (2007).

Less Is More in Decision Theory

Simplicity and Steve Jobs: "That's been one of my mantras—focus and simplicity. Simple can be harder than complex: You have to work hard to get your thinking clean to make it simple. But it's worth it in the end because once you get there, you can move mountains." *BusinessWeek*, May 25, 1998.

Heuristics as powerful—and necessary—shortcuts: Gigerenzer and Brighton (2009) bust the following myth, as presented in *The Selfish Gene* by Richard Dawkins, in which we find the following about how a baseball outfielder catches a ball: "[H]e behaves as if he had solved a set of differential equations in predicting the trajectory of the ball.… At some subconscious level, something functionally equivalent to the mathematical calculations is going on."

Not quite, Professor Dawkins. Gerd Gigerenzer *et al.* counter by saying that none of that is done. They write the following:

> Instead, experiments have shown that players rely on several heuristics. The gaze heuristic is the simplest one and works if the ball is already high up in the air: Fix your gaze on the ball, start running, and adjust your running speed so that the angle of gaze remains constant. A player who relies on the gaze heuristic can ignore all causal variables necessary to compute the trajectory of the ball—the initial distance, velocity, angle, air resistance, speed and direction of wind, and spin, among others. By paying attention to only one variable, the player will end up where the ball comes down without computing the exact spot.
>
> The same heuristic is also used by animal species for catching prey and

for intercepting potential mates. In pursuit and predation, bats, birds, and dragonflies maintain a constant optical angle between themselves and their prey, as do dogs when catching a Frisbee.

Additional examples:

To choose a mate, a peahen uses a heuristic: Rather than investigating all peacocks posing and displaying in a lek eager to get her attention or weighting and adding all male features to calculate the one with the highest expected utility, she investigates only three or four, and chooses the one with the largest number of eyespots.

Just like humans. Another example:

To measure the area of a nest cavity, a narrow crack in a rock, an ant has no yardstick but a rule of thumb: Run around on an irregular path for a fixed period while laying down a pheromone trail, and then leave. Return, move around on a different irregular path, and estimate the size of the cavity by the frequency of encountering the old trail. This heuristic is remarkably precise.

Other: Czerlinski and Gigerenzer *et al.* (1999), Goldstein and Gigerenzer (1999), Gigerenzer (2008).

Makridakis, forecasting, and less is more: Makridakis *et al.* (1982, 1993), Makridakis and Hibon (2000), Makridakis and Taleb (2009).

Heuristic to measure risks: Taleb, Canetti *et al.* (2012)—with IMF staff.

Lindy Effects and Associated Topics

The Lindy effect was demonstrated in Mandelbrot (1997). Initially he used it for the artistic production, bounded by the life of the producer. In our conversations toward the end of his life, I suggested the boundary perishable/nonperishable and he agreed that the nonperishable would be powerlaw distributed while the perishable (the initial Lindy story) worked as a mere metaphor. Depending on whether we condition for knowledge of the initial time, the remaining lifetime for the exponential remains constant regardless of future condition, for powerlaw increases with time since inception, by a factor of (α/1-α), where α is the tail exponent; for Gaussian or

semi-Gaussian it decreases.

Gott: Gott (1993, 1994) presented the Copernican idea but did not properly condition the probability; corrected in Caves (2000). See discussion in Rees (2003), a treatment of the paradox in Bostrom (2002).

Survival papers and distributional properties: Often powerlaws are mistaken for exponential distributions, owing to lack of data in the tails. So I assume a priori that an exponential is likely to be powerlaw, but not the reverse, as the error in the opposite direction is vastly less likely. Pigolotti *et al.* (2005). For empires, Arbesman (2011), Khmaladze *et al.* (2007, 2010), Taagepera (1978, 1979). For firms: Fujiwara. Also Turchin (2003, 2009).

Conditional expected time of survival across distributions: Sornette and Knopoff (1997). They show how, paradoxically, the longer one waits for an earthquake, the longer he would be expected to wait.

Other Neomania

Le Corbusier: Christopher Caldwell, "Revolting High Rises," *New York Times*, November 27, 2005.

Cairns and ancient measures: Cairns (2007). His work was brought to my attention by Yoav Brand, who graciously offered me his book after a lecture.

Nonteleological design: How buildings mutate and change, Brand (1995).

The Dog: *Moral,* ii. 11; 1208 b 11. "And he says that when a dog was accustomed always to sleep on the same tile, Empedokles was asked why the dog always sleeps on the same tile, and he answered that the dog had some likeness to the tile, so that the likeness is the reason for its frequenting it."

General and Philosophical Discussions of Medicine

Medicina soror philosophiae: For reflective histories of medicine, Mudry (2006), Pigeaud (2006); Camguillem (1995) discussion of iatrogenics. For the spirit, Pager (1996), Bates (1995).

Islamic medicine: Porman and Savage-Smith (2007), Djebbar (2001).

De motu animali ***and attempts to mathematize medicine:*** In Wear (1995). Let me reiterate: math is good, the wrong math is not good.

Ancient medicine: Edelstein (1987), Lonrig (1998). Vivian Nutton's *Ancient Medicine* (Nutton [2004]) is informative, but near-silent about the empiricists,

and not too detailed about ancient practices outside of a few standard treatises. More on medicine (skeptics and methodists) in the monumental Zeller (1905) or even better the superb *Les Sceptiques Grecs* by Brochard.

Oranges: As they are named in Modern Greek, *portokali*, a corruption of "Portuguese"—further corrupted in Levantine Arabic into *burduqan*, and present under that name in the Sicilian dialect.

Medical heuristics: Palmieri (2003).

Medieval and Renaissance: French (2003).

General history: Conrad *et al.* (1995), Porter (2002, 2003), Meslin *et al.* (2006), Kennedy (2004).

Iatrogenics: Sharpe and Faden (1998), most complete; Illich (1995) the first movement; Hadler (2009) for the back, Duffin (1999), Welsh *et al.* (2011) on overdiagnosis (though no argument about noise/signal and filtering), Lebrun (1995).

Agency and iatrogenics: Just a random example: "Surgeons do more operations if they're on the board of surgery centers," June 22, 2012, "The Daily Stat," *Harvard Business Review*.

More amusing historical perspective of iatrogenics: Gustave Jules A. Witkowski, 1889, *Le mal qu'on a dit des médecins.*

Rationalism/Galenism: Garicia-Ballester (1995).

Montaigne: *"Mais ils ont cet heur, selon Nicocles, que le soleil esclaire leur succez, et la terre cache leur faute; et, outre-cela, ils ont une façon bien avantageuse de se servir de toutes sortes d'evenemens, car ce que la fortune, ce que la nature, ou quelque autre cause estrangere (desquelles le nombre est infini) produit en nous de bon et de salutaire, c'est le privilege de la medecine de se l'attribuer. Tous les heureux succez qui arrivent au patient qui est soubs son regime, c'est d'elle qu'il les tient. Les occasions qui m'ont guery, moy, et qui guerissent mille autres qui n'appellent point les medecins à leurs secours, ils les usurpent en leurs subjects; et, quant aux mauvais accidents, ou ils les desavouent tout à fait, en attribuant la coulpe au patient par des raisons si vaines qu'ils n'ont garde de faillir d'en trouver tousjours assez bon nombre de telles. …"* [Note the detection of the attribution problem.]

On demandoit à un Lacedemonien qui l'avoit fait vivre sain si long temps: L'ignorance de la medecine, respondit il.

Et Adrian l'Empereur crioit sans cesse, en mourant, que la presse des

medecins l'avoit tué.

Modern alternative medicine: Singh and Edzard (2008)—they had their skin in the game, as they were sued for it.

Homeopathy and empirical evidence: Goldacre (2007). See also the highly readable *Bad Science,* Goldacre (2009).

Modern evidence-based medicine: Manual in Sacket *et al.* (1998). Flaws of rationalistic methods, Silverman (1999), Gauch (2009), Sestini and Irving (2009).

Icing: Collins (2008): "There is insufficient evidence to suggest that cryotherapy improves clinical outcome in the management of soft tissue injuries." I could not find papers saying the opposite. What benefits are proffered seem so marginal it is not even funny.

Convexity of blood pressure: Numbers from Welch *et al.* (2011).

Jensen's inequality and pulmonary ventilators: Brewster *et al.* (2005), Graham *et al.* (2005), Mutch *et al.* (2007).

Paracelsus: Interesting character as a rebel; alas, seems to have been hijacked by homeopathy advocates such as Coulter (2000). Biographies in Ball (2006), Bechtel (1970), Alendy (1937).

Immortalization: Gray (2011).

Stendhal: *Le Rouge et le noir: "La besogne de cette journée sera longue et rude, fortifions-nous par un premier déjeuner; le second viendra à dix heures pendant la grand'messe*." Chapitre XXVIII.

Specific Medical Topics

Note that the concern of this author is not evidence, but rather absence of it and how researchers manage such a problem. The focus is in detecting missed convexities.

Effectiveness of low-calorie sweeteners: One gets plenty of information by looking at studies by defenders with vested interests. De la Hunty *et al.* (2006) shows "advantages" to aspartame, with a meta-analysis, but focusing on the calorie-in calorie-out method, not overall weight gains. But reading it closely uncovers that the core is missing: "Some compensation for the substituted energy occurs but this is only about one-third of the energy replaced and is *probably* [emphasis mine] less than when using soft drinks sweetened with

aspartame. Nevertheless these compensation values are derived from short-term studies." Obviously, the paper was financed by a maker of aspartame. A better study, Anderson *et al.* (2012), though marred with conflict of interest (authors' support from food companies), concludes: "there is no evidence that LCS (low calorie sweeteners) can be claimed to be a cause of higher body weight in adults. Similarly evidence supporting a role in weight management is lacking." The last sentence is the only one that I can pay attention to as it is evidence "against interest." Had there been benefits, we would have known about them. In other words, we are incurring iatrogenics of these sweets-without-calories without evidence, as of 2012, that they even work!

Mithridatization and hormesis: In Pliny, Kaiser (2003), Rattan (2008), Calabrese and Baldwin (2002, 2003a, 2003b). Note that they miss the convexity argument or the insight about the departure from the norm—hormesis might just be reinstatement of normalcy.

Fasting and hormesis: Martin, Mattson *et al.* (2006). Cancer treatment and fasting, Longo *et al.* (2008), Safdie *et al.* (2009), Raffaghelo *et al.* (2010)); on yeast and longevity under restriction, Fabrizio *et al.* (2001); SIRT1, Longo *et al.* (2006), Michan *et al.* (2010); review work in Blagosklonny *et al.* (2010).

Definition of hormesis: Mattson (2008) for local definition, Danchin *et al.* (2011) for more complex-systems approach.

Aging, longevity, and hormesis: An extremely rich research; Radak *et al.* (2005), Rattan (2008), Cypster and Johnson (2002) for the C-elegans; Gems and Partridge (2008), Haylick (2001), Masoro (1998), Parsons (2000); for inflammation and Alzheimer's, Finch *et al.* (2001).

Bone density and load: Dook (1997) for females, Andreoli *et al.* (2001) for more general athletes; Scott, Khan, *et al.* (2008) for general exercise. Aging for females: Solomon (1997), Rautava *et al.* (2007); Conroy *et al.* (1993) for young females.

Bone density and bicycle riding: Nichols *et al.* (2003), Barry *et al.* (2008).

Bone density and Olympic-style weightlifting: Some "weightlifting" studies mistake the resistance exercise on machines for real naturalistic weightlifting that stresses the skeleton. Conroy *et al.* (1993) is a more ecologically robust study because it focuses on weight.

Thyroid: Earle (1975).

Cholesterol: Non-naive look, Scanu and Edelstein (2008).

Lewontin and life expectancy: Lewontin (1993). Got idea for the potential unreliability of the Lewontin estimation and was directed to the CDC data from some article on the Web I can't remember.

Outdoors not sports: Rose *et al.* (2008). Higher levels of total time spent outdoors, rather than at sports per se, were associated with less myopia and a more hyperopic mean refraction, after adjusting for near work, parental myopia, and ethnicity.

"Neurobabble," "brain porn" studies: Weisberg (2008), McCabe (2008), also "neuroscience and the law," report by the U.K. Royal Society. Note that the writer Jonah Lehrer used brain porn quite effectively, building a narrative using some loose brain story, playing the narrative fallacy to the hilt—until he was caught creating both narrative and data to back it up.

The pressure on dentists to generate revenues: "Dental Abuse Seen Driven by Private Equity Investments," Sydney P. Freedberg, Bloomberg News, May 17, 2012.

Significance: Simply, people in social science should not be using statistics any more than an accountant should be given a surgeon's knife. The problem of misunderstanding significance affects professionals. See McCloskey and Ziliak (1996), Ziliak and McCloskey (2008), Soyer and Hogarth (2011), Kahneman and Tversky (1971), Taleb and Goldstein (2012).

Practitioners and theoreticians in mathematical finance failing to understand an elementary notion in statistics in spite of all the hype: Evidence in Taleb and Goldstein (2007).

Missing nonlinearities of dose response: The case of radiation is rather stark, Neumaier *et al.* (2012). "The standard model currently in use applies a linear scale, extrapolating cancer risk from high doses to low doses of ionizing radiation. However, our discovery of DSB clustering over such large distances casts considerable doubts on the general assumption that risk to ionizing radiation is proportional to dose, and instead provides a mechanism that could more accurately address risk dose dependency of ionizing radiation." Radiation hormesis is the idea that low-level radiation causes hormetic overreaction with protective effects. Also see Aurengo (2005).

Statins and convexity: For instance, with statin drugs routinely prescribed to lower blood lipids, although the result is statistically significant for a certain class of people, the effect is minor. "High-risk men aged 30–69 years should

be advised that about 50 patients need to be treated for 5 years to prevent one [cardiovascular] event" (Abramson and Wright, 2007).

Statins side effects and (more or less) hidden risks: Side effects in musculoskeletal harm or just pain, Women, Speed *et al.* (2012). General assessment, Hilton-Jones (2009), Hu Chung *et al.* (2012). Roberts (2012) shows another aspect of convexity of benefits, hence harm in marginal cases. Fernandez *et al.* (2011) shows where clinical trials do not reflect myopathy risks. Blaha *et al.* (2012) shows "increased risks for healthy patients." Also, Reedberg and Katz (2012); Hamazaki et al.: "The absolute effect of statins on all-cause mortality is rather small, if any."

Harlan Krumholz, *Forbes*, April 29, 2011:

> Problem is that drugs that improve blood test results may not lower risk. For example, many drugs that reduce LDL or raise HDL or lower blood sugar or blood pressure, do not, against all expectations, lower risk—and in some cases they increase risk.
>
> This is particularly true when considering treatment options to prevent a future event such as a heart attack. Unfortunately, for many drugs that affect risk factors, studies that investigate whether patients benefit are either not done or delayed. This is the case with ezetimibe, a Merck agent that reduces LDL. Because the study that will include information about patient outcomes will only be completed when ezetimibe comes off patent, we will not know how it actually affects risk for a few more years. This billion dollar drug's approval and sales have been solely based on its effect on a blood test.
>
> For the fibrates, though, we are more fortunate. There are studies of patient outcomes, and fenofibrate, the Abbott drug, has been tested twice in large studies. In both, the drug failed to reduce the risk of the patients taking it even as it very effectively lowered their triglyceride levels. Most recently, in a $300 million trial by the National Institutes of Health, no benefit was shown for the Abbott drug when it was combined with a statin —compounded by a suggested harm for women. The former concern is sufficiently high to have prompted the FDA to convene an advisory committee to review the findings.

Back: McGill (2007); iatrogenics surgery or epidural, Hadler (2009), Sayre

(2010).

Doctor's strikes: There have been a few episodes of hospital strikes, leading to the cancellation of elective surgeries but not emergency-related services. The data are not ample, but can give us insights if interpreted in *via negativa* mode. Extracting the effect of elective surgery, Argeseanu *et al.* (2008). See also Allebeck (1985), Gruber and Kleiner (2010), Siegel-Itzkovich (2000).

Diabetes and pharmacological treatments (ACCORD study): The ACCORD study (Action to Control Cardiovascular Risk in Diabetes) found no gain from lowering blood glucose, or other metrics—it may be more opaque than a simple glucose problem remedied by pharmacological means. Synthesis, Skyler *et al.* (2009), old methods, Westman and Vernon (2008).

Discussions of diabetes and diet: Taylor (2008), reversal in Lim *et al.* (2011), Boucher *et al.* (2004), Shimakuru *et al.* (2010); diabetes management by diet alone, early insights in Wilson *et al.* (1980). Couzin, "Deaths in Diabetes Trial Challenge a Long-Held Theory," *Science* 15 (February 2008): 884–885. Diabetes reversal and bariatric (or other) surgery: Pories (1995), Guidone *et al.* (2006), Rubino *et al.* 2006.

Autophagy for cancer: Kondo *et al.* (2005).

Autophagy (general): Danchin *et al.* (2011), Congcong *et al.* (2012).

Jensen's inequality in medicine and workout: Many such as Schnohr and Marott (2011) got close to dealing with the fact that extreme sprinting and nothing (as a barbell) outperforms steady exercise, but missed the convexity bias part.

Art De Vany and Jensen's inequality: Art De Vany, private correspondence: "Tissue gains are increasing but convex with nutrient intake (the curve is rising, but at a diminishing rate). This has to be the case for the point of origin to be a steady state solution. This implies that weight gain, including fat, is higher at the average intake than it is on a varying intake of the same calories and nutrients. Muscle and fat compete for substrate, so a fatter person will shift nutrient partitioning toward muscle because body fat induces insulin resistance in muscle. Insulin operates in a pulsate release and is far more effective with that pattern than with the chronic elevation induced by six meals a day. On the downside, where fat and muscle are lost, the curve is negatively sloped but declines at a diminishing rate (concave). This means you lose more fat feeding intermittently than continuously. The loss at the

average intake (six per day keeps the variation of the average small) is less than the loss at the same intake but one that varies between a small intake and a large one. A more subtle point: you lose more weight when you eat at the average than intermittently, but that is because you lose more muscle in chronic deprivation than intermittent deprivation. Intermittent eating yields a superior body composition."

Starvation, intermittent fasting, and aging: For the neuronal resistance and brain aging, Anson, Guo, *et al.* (2003), Mattson *et al.* (2005), Martin, Mattson *et al.* (2006), Halagappa, Guo, *et al.* (2007), Stranahan and Mattson (2012).

Caloric restriction: Harrison (1984), Wiendruch (1996), Pischon (2008).

Intense exercise: Synthesis of the literature on the effect of episodic energy imbalance, in De Vany (2011), who also, as a bonus, examines powerlaw effects.

Missing the point that pills are more speculative: Stip (2010) spends time on *via positiva* methods to extend life with complicated pharma stories.

Glucose and willpower: Note the effect of glucose making people sharper and helping willpower from experiments by Baumeister, see Kahneman (2011), might only apply to metabolically unfit persons. See Kurzban (2011) for a look at the statistical tools.

Cluster of ailments from lack of randomness, as presented in prologue: Yaffe and Blackwell (2004), Razay and Wilcock (1994); Alzheimer and hyperinsulenemia, Luchsinger, Tang, *et al.* (2004), Janson, Laedtke, *et al.* (2004).

Starvation and the brain: Stranahan and Mattson (2012). Long-held belief that the brain needed glucose, not ketones, and that the brain does not go through autophagy, progressively corrected.

Ramadan and effect of fasting: Ramadan is not interesting because people fast for only about 12 hours, depending on the season (someone who fasts from dinner to lunch can get 17 hours without food, which is practiced by this author). Further, they gorge themselves at dawn, and load on carbohydrates with, in my experience, the sweets of Tripoli (Lebanon). Nevertheless, some significance. Trabelsi *et al.* (2012), Akanji *et al.* (2012).

Benefits of stress: For the different effects of the two types of stressors, short and chronic, Dhabar (2009); for the benefits of stress on boosting immunity and cancer resistance, Dhabhar *et al.* (2010), Dhabhar *et al.* (2012).

Iatrogenics of hygiene and systematic elimination of germs: Rook (2011), Garner *et al.* (2006), Mégraud and Lamouliatte (1992) for Helyobacter.

The Paleo crowd, De Vany, Gary Taubes, and friends: Taubes (2008, 2011), De Vany (2011); evolutionary anthropology, Carrera-Bastos *et al.* (2011), Kaplan *et al.* (2000).

BOOK VII: The Ethics of Fragility and Antifragility

Modern philosophical discussions on capitalism: No interest in such a simple heuristic as skin in the game, even in insightful discourses such as Cuillerai (2009).

Courage in history: Berns *et al.* (2010).

Gladiators: Veyne (1999).

Treadmill: Lucretius, *Nimirum quia non bene norat quæ esset habendi / Finis, et omnino quoad crescat vera voluptas.*

Group and collective: Haidt (2012).

Adam Smith on capitalism: "A word he never uttered": Simon Schama, private communication.

Stiglitz et al. dangerous report: Joseph E. Stiglitz, Jonathan M. Orszag, and Peter R. Orszag, "Implications of the New Fannie Mae and Freddie Mac Risk-based Capital Standard," *Fannie Mae Papers*, Volume I, Issue 2, March 2002.

Meyer Lansky: Attributed to Ralph Salerno, retired NYPD mob investigator, in Ferrante (2011).

Unsavory activities by pharma finding patients rather than treatments: Stories of direct and indirect corruption, particularly in the psychiatric domain. A professor of psychiatry at Harvard Medical School received $1.6 million from pharma. "Thanks to him, children as young as two years old are now being diagnosed with bipolar disorder …" Marcia Angell, *The New York Review of Books*. Angell used to be the editor of *The New England Journal of Medicine* and distrusts a large number of clinical studies. Further, how money is not spent on speculative research, but on "safe" bets with regular drugs, Light and Lexchin (2012).

Contradicting studies: Kahneman brought to my attention studies such as Malmendier and Tate (2008, 2009) showing managers investing more than needed in their companies, hence excess skin in the game as a result of overconfidence. Myron Scholes and Robert Merton had investments in LTCM. Indeed—but overall the free option dominates (just measure the aggregate payment of managers relative to gains by shareholders). There are "fools of randomness" and "crooks of randomness"; we often observe a

combination. (Credit: Nicolas Tabardel.)

Asymmetries and extractive: Acemoglu and Robinson (2012) discusses an asymmetry with their notion of extractive economic institutions and environment, in which someone gets rich at the expense of someone else, the opposite of the convex collaborative framework in which one's wealth leads to a compounding pie. Role of institutions, North (1990).

Caviar socialism and Burnyeat's problem: Riffard (2004), Burnyeat (1984), Wai-Hung (2002).

Collective blindness and diffusion of responsibility: In the animal domain (ants), Deneubourg, Goss *et al.* (1983), Deneubourg, Pasteels *et al.* (1983).

Life and socialization in Rome: Veyne (2001).

Elephant in the room: Things that everyone knows but remain undiscussed. Zerubavel (2006).

Mortality of large firms: Higher than expected, Greenwood and Suddaby (2006), comment Stubbart and Knight (2006). The best test is to take the S&P 100 or S&P 500 and look at its composition through time. The other one of course is in the literature on mergers.

Information cascades: The mechanism by which the crowd exacerbates fallacies, illusions, and rumors, Sunstein (2009) for a synthesis.

Alan Blinder problem: *Wall Street Journal* article with undisclosed conflict of interest: "Blanket Deposit Insurance Is a Bad Idea," Oct. 15, 2008, coauthored with R. Glenn Hubbard, dean of Columbia University Business School.

Comparative performance of family businesses: McConaughy and Fialco (2001), Le Breton–Miller and Miller (2006), Mackie (2001).

Skin in the game: Taleb and Martin (2012a).

Data Mining, Big Data, and the Researcher's Option, etc.

Misunderstanding in social science literature: Typical mistake, consider the ignorance of the problem by hyperactive promoters of the idea such as Ayres (2007): "Want to hedge a large purchase of Euros? Turns out you should sell a carefully balanced portfolio of twenty-six other stocks and commodities that might include Wal-Mart stock," p. 11.

Stan Young's crusade: Young and Carr (2011). Also Ioannides (2005, 2007).

Doxastic commitment: Levi (1980).

Salt: Very convincing Freedman and Petitti (2001), relies on visualization of data rather than metrics. Note "neither author consults for the salt industry," the kind of thing I read *first*.

Graph on Big Data: By Monte Carlo simulation; used >0.1, or beyond what correlations are loved in social science (it is hard to analytically do the analysis because of the need for large matrices to remain positive-definite). The convexity is invariant to the correlation threshold.

Solution to the researcher's bias in clinical trials: Goldacre (2009) suggests the establishment of a database of trials, forcing researchers to record their failures. Anything is better than what we got.

The collective and fragility: The power of the collective rests on benefits from efficiency, hence fragility: people start substituting collective judgment for individual judgment. This works fine—it is faster and cheaper (hence more *efficient*) than having to reinvent the wheel individually. But like everything that is a shortcut, it ends blowing up in our faces. In the world in which we live the effect is compounded—the scale is larger and larger; the collective is planetary.

Jobs and artisan ethics: This makes me worry: "Playboy: 'Are you saying that the people who made PCjr don't have that kind of pride in the product?' Jobs: 'If they did, they wouldn't have made the PCjr.' " *Playboy* [*sic*], Feb. 1, 1985.

Busting the hypothesis of hyperbolic discounting: Read and Airoldi (2012).

Other discussions of Big Data and researchers gaming the system: Baumeister *et al.* (2007) about self-reporting in psychology. Kerr (1998) about hypothesis following the results, and post hoc in Yauan and Maxwell; Yarkoni for the large *M* (dimension) low *N* (data) problem.

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