Why Quantitative Prediction of the Stock Market Fails

Aaron Krowne

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1 Introduction

> *Math doesn't drive financial markets, people drive financial markets, and people are not predictable. We do not yet have a universal theory of human behavior or human motivation. Given that that's so, we're not likely to have robust models of financial market behavior that will always work, and I think the hubris of the mathematician is to ignore that fact.*
>
> —Peter Fisher, executive vice president of the Federal Reserve Bank of New York, February, 2000 [PBS(2000)]

In the naive approach to investing, especially common among beginners and amateurs, there prevails a mindset that one can predict the future performance of markets (or individual equities) by extrapolating "smoothly" from past performance. In other words, people seem to automatically think that by looking at a curve of past performance of an asset, they can extend the same trends into future performance for the same amount of time.

This is a reasonable mindset, but not for the stock market. Using it for investing leads to classic, disastrous mistakes. I remember as a nouveaux investor obsessively scanning stock charts for hours, searching for ones that had "bottommed out" and were "beginning to rise," so that I could buy them at this moment of "breakout" and reap windfall profits. Needless to say, this approach didn't work out too well. This is because, in essence, everything in quotes in the previous paragraph is nonsense.

In this paper I will briefly explain why this mindset, which I call "quantitative prediction," fails. Hopefully, this will allow some beginners to avoid passing through this unfortunate phase of investing, and spare themselves the emotional damage that may forever sour their opinion of it.

2 Mathematical Character of Market Assets

In the introduction, I mentioned "smooth extrapolation." In other words, the approach to quantitative prediction is to look at some past window for an investment, simplify or approximate the trend visible in this window (up, down,

linear, quadratic, exponential, etc.), and extend this trend into the next future window of similar size.

This is a mathematically sound approach for something which in mathematics are called *analytic functions* [PlanetMath(2005)]. "Analytic" basically means "smooth," and hence, for smooth things, you can extrapolate like this. That is, for some "window" on a function, you can provide a same or lower-order (less complex) approximation, which you can extend *outside* that window with very good results.

In the most simplistic view, "analytic" means that the more you "zoom in" on the function, the more it looks like a *line*. Thus, lines will always suffice as a reasonable fallback approximation or extrapolation for analytic functions.

People seem to like to treat equity charts as analytic functions. Sadly, this couldn't be farther from the reality—a market asset's price is not a smooth, analytic function! This is something that is *plain to see*, but we instinctively wish it away every time we look at a chart.

First of all, one must note that the chart isn't even *continuous*. The price is updated with some regular frequency depending on how the particular exchange is run. In essence, the price is determined in discrete *rounds* of trading, during which one or many exchanges take place. The price of the last exchange is the "ticker price." A daily chart is made from sequencing a whole day of these exchange prices. Charts for longer periods of time are made from placing these daily charts end-to-end (then of course, with charting tools, one can manipulate them further to different time scales).

Thus, the essence of a market asset's chart is actually a series of *disconnected points* which we happen to like to draw lines through! This comforts us, because it makes the chart look like "one thing;" like a single, mathematical curve. It's just like "connect the dots!"

Yet once in a while, the underlying discontinuous nature of market assets pokes through the self-deception; it is not uncommon for stocks or markets to jump at the beginning of a trading session, or even intra-session, upon the release of new information, to a point extremely far from the last exchange value. This induces a sharp "cliff" in the chart, and people are amazed how quickly the value changed.

So a stock, or market asset in general, has a chart that is really just a series of disconnected points, and these points are based on how people feel about the asset's worth at those instants. These feelings are based on how other people are acting, the prevailing information (whether right or wrong), and varying projections on the future of the underlying company (or companies) and changes in the world. In sum, these charts can go pretty much anywhere, until they "price in" information that is irrefutably true and widely known.

In Appendix A, I discuss another major reason why the market fails to behave like the kind of artifact analyzed in mathematics.

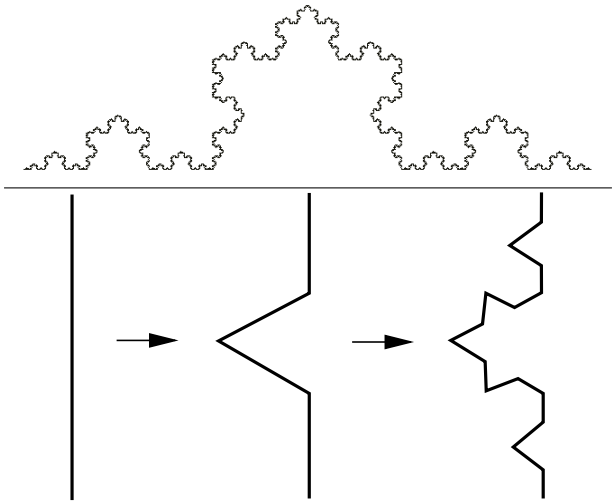


Figure 1: **The Koch Curve**: A famous fractal. Above, a picture of the curve with pixel-level detail. Below, the simple "replacement rule" that generates the curve as the rule is applied repeatedly.

2.1 Getting Specific: Random Fractals

Because of this random character of the market, when you look at a market asset's chart, over any time period, *the chart looks the same*. There is a specific mathematical term for such a shape: it is called a *random fractal*.

A *fractal* in general is simply a mathematical shape that looks "the same" at all scales [Mandelbrot(1982)] (this property is called *self-similarity*). It does not have to be *exactly* the same (though some are), but the point is that if you zoom in (or out) on a fractal shape or curve, it will look (and behave) very similar to how it does at any other scale. In Figure 1, a famous yet simple fractal called the *Koch curve* is shown.

Fractals are the antithesis of analytic curves, which look only more "flat" as you zoom in.

A *random fractal* is one which looks jagged and impossible to characterize at every scale. Think of a mountain range (See Figure 2). The Himalayas look jagged; zoom in on them and you have a couple of peaks, which still look jagged. Zoom in on the side of one of these, and you have a jagged incline, based on the random shape of the mountain itself. Zoom in on part of this, and you have boulders, the contours of which go up and down—there is no smooth ascent, despite the fact that we know the mountain will go up (this is tantamount to foreknowledge—a bug crawling on the rocks would not know it). Zoom in on this, you get rocks and pebbles which create a rough silhouette that goes both up and down, and so forth.

The market is a lot like this.

Figure 2: **Generating a random fractal terrain.** This picture shows a generated terrain profile as the randomness inverse-scale-factor H falls (as it gets smaller, randomness rises). The final "curve," where $H = 0.2$, looks strikingly like a stock price chart. Courtesy of `http://www.gameprogrammer.com/fractal.html`.

3 The Quantitative Prediction Mistake

Because a random fractal is *random*, you can't really extrapolate any segment of it to any neighboring segments. After all, it's random, not smooth; you never know where it's going to go.

The quantitative prediction mistake is essentially this: you pick the point on the chart at the current time. Then you pick some interval, I, (for instance, 6 months) to look back into the past. Over this interval, you find a *rule* that approximates what the chart did (or put in a more loose way, how the asset performed). Then you gleefully apply this trend rule into the future interval of the same size as I, starting from the present point (the current price of the asset), and claim that you know where the price will be at the end of the next interval I.

But the problem with this is, again, that because market asset price charts have a strong, often predominating random fractal character—*you can't extrapolate a rule from a past fixed interval to a future fixed interval of similar size.* If the past interval was 6 months, you might get lucky for the first one week or one month into the future sheerly because prices don't *normally* change too fast, but the closer you get to 6 months, the more random the outcome will be. And the less it will resemble what happened in the past 6 months.

This process of attempting to quantitatively project is illustrated in Figure 3, a series of charts of the same stock. The underlying security was chosen arbitrarily. From these charts, it is clear that all of the linear projections are pretty bad, and it would be unwise to invest based on them. Not only does the projection line extend off very far from the final price (sometimes to a negative or ridiculously high range), but the *slopes* of the lines don't even match up! However, the real counter-intuitive part is that the projections *get no better* as the time window is progressively narrowed. Because of the *randomness* of the random fractal behavior, *there is no interval, no matter how small, in which*

accurate mathematical predictions can be made.

In this example, a linear projection was chosen—but only to make a basic point. Any quantitative projection, no matter how sophisticated, would be doomed to the same fate. In fact, randomness can essentially be defined as the property of a series which causes it to resist *a priori* mathematical prediction.

The reader might object at this point that "no one is really this dumb," except perhaps people who haven't even *begun* to try or seriously think about investing. For them, after all, the market is a jumble of quasi-superstitious beliefs (perhaps influenced by movies like *Pi*, which implied that rigid, simple mathematical rules somehow underly and explain all prices in the stock market).

Ah, but stupidity and naivity go far when they are sufficiently sugar-coated, shrink-wrapped, and expensively marketed.

Accordingly, I've noticed a number of areas where respectable, highly-paid, experienced, trusted persons are still making the quantitative prediction mistake:

1. The "quant" advisors. Often general financial writers or members of stock advisory services (perhaps making up the entire service), these people purport to divine how to invest in the future based on analysis of market and asset charts. But the people that fall for this never go back and check the track record of these guys' predictions (indeed, it'd probably be impossible to get the data, not unintentionally).

2. Mutual fund companies (and their customers).

3. People who advocate using mutual fund *manager* track records.

The last two are especially potent hazards for the typical investor, who by semi-necessity (and partially by marketing) puts a large portion of their investing assets (indeed, life's savings) in mutual funds.

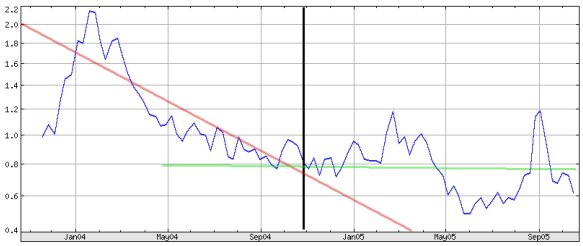
3.1 An Application: Mutual Funds

The Motley Fool (and others), I believe, have done a sufficient job of eviscerating mutual funds' performance relative to dumb, passive market indices [Fool(2005)]. But why is it that these funds are still popular, and indeed, dominate people's retirement portfolios, despite the availability of index funds from the same providers?

The reason is that mutual fund vendors can still make the funds look attractive in their marketing materials, *as long as they trick the buyer into making the quantitative prediction mistake.*

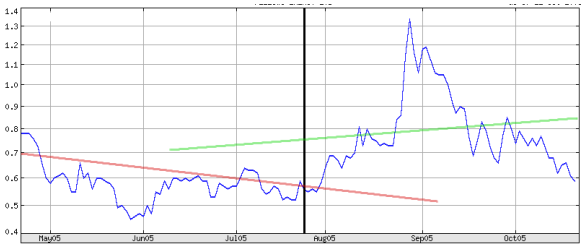
Mutual fund prospectuses and reports are notoriously dishonest. Unless it would be absolutely obvious to do so, they manipulate how much of the past data you can see to hide the random fractal nature of their funds from you, showing just the "up, up, and away" portion of past performance. This can be done by arbitrarily setting the chart window to focus on more successful recent years. More ominously, it can be done by retiring poorly-performing funds and

2 years :



1 year :

6 months :



3 months :

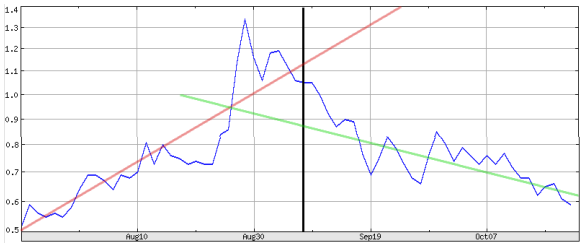


Figure 3: **Attempting to project where the price of a stock is heading**. Shown are four past intervals, all ending at the present time. Each interval is split into two segments: the first, which the linear projection (red) is generated from, and the second (green), where a rough linear regression of where the price *actually went* is shown. Note how skew these turn out to be.

starting new ones. This is why mutual funds all seem to be just a few years old—if you bury the data about failed past mutual funds (and all will start to fail when their luck runs out), you can tailor what's left to select for recent success.

But when buyers naturally assume this success will continue into the future, as the mutual fund prospectuses beg them to, they will become sorely disappointed. If comprehensive data were included in prospectuses, buyers would clearly see that their odds are a coin toss, relative to indexes.

People seem to think there is a clever way out of this: instead of tracking mutual funds, track mutual fund *managers*. These are the people that run the mutual funds, determining which assets to buy and sell. The theory seems to be that, if the performance of individual funds can't be projected easily into the future, then this must instead be true for fund managers. After all, some people are more skillful than others at practices, and investing is a practice.

But as the stock selection of fund managers approaches randomness relative to basic market indexes, *they themselves* become describable by the random fractal model. Indeed, analysis of "star" fund managers, who have broken from their parent financial institutions to start their own funds, shows that the results are no better than a random sampling [Jaffe(2005)]. That is, if you select the cream of the crop of fund managers in the past ten years (for instance), in the next ten years, most of this "cream" will have settled into mediocrity (or worse), leaving a completely random, new "cream" at the top. Often some of the best of the past era become the absolute worst in the future era. More on this later.

3.2 When Quantitative Analysis is Actually Useful

This isn't to say that there's nothing to be gained from quantitative analysis of market assets. It isn't such analysis wholesale that's bad; what's bad is when you try to *predict* future asset prices based on *rigid rules* divined from charts of past prices.

Quantitative analysis is still useful for a number of other investment tasks:

- Determining volatility and risk.
- Setting up and maintaining hedges.
- Measuring current investor sentiment.

Detailing the first two items is not the point of this piece, but the last item, at least begs some explanation. You see, you can invest more wisely in the short term if you understand investor sentiment fairly well. However, it is difficult to run around and interview all the investors in a market to find out what they think, how they feel, and what information they have. In fact, they probably wouldn't be honest with you anyway. But the stock price never lies about how the market feels. In this sense, it is the best proxy for understanding how the market feels *at the current time*, which you can combine with real-world data

to get some short-term notion of where the asset will go if sentiment stays the same (or changes).

While these are useful investment modalities, I would claim that they aren't nearly as useful as value investing, the approach laid out in the next section. Basically, it is only large-scale investors with immense assets (like banks and billionaires) who can afford to care about applying quantitative analysis in the above ways on a continual basis.

4 How To Really Invest

Investing as quantitative prediction is identical to gambling. People who blow off the stock market as "gambling" actually have this specific approach in mind. And this tends to be because, as above, they haven't seriously tried or studied investing, and so they conceptualize it based on this wrong intuition. Good for them, then, that they have the sense to stay away while this is their model of investing.

But true, profitable investing is a real thing. And there is a meta-method which leads to consistent success over lifetime investing time horizons. This approach is called *value investing* [Graham(1973)], and it basically says that investing decisions should be anchored in the real-world value of the underlying company or asset.

Well, "duh," right? But this is easier said than implemented, and this method wraps up a lot of the "hard part" of investing in a neat little platitude. In reality, doing the rigorous research to find under-valued assets, or being correct about the future prospects of an asset *based on facts and trends in the real world*, are quite difficult (though not unattainable with some serious work).

The value investing approach is exemplified by enourmously successful guys like Warren Buffet, Benjamin Graham, and Peter Lynch [Graham(1973), Lynch and Rothchild(1989)]. These fellows (and those whose money they managed) became extremely rich over many years, through patient and gradual value investing, completely ignoring "the charts" and quantitative analyses, and only being concerned with the current price and intrinsic value of an asset.

The quantitative prediction approach is exemplified by train wrecks like Long Term Capital Management (LTCM) [Lowenstein(2001)] and the trading floor at Enron (which switched from being randomly successful enough to cover for the rest of the company's impropriety to being a colossal failure that could no longer hide wrongdoing in a mountain of profits) [McLean and Elkind(2003)].

In fact, I don't believe a quantitative prediction investing method has ever been shown to lead to profit on lifetime investing timescales *after* it was selected and utilized. And on shorter investing timescales, there's no way to know which methods will randomly end up successful out of a pool of contenders. Thus, people can always point to this or that method that was successful in the past; but this is precisely the problem described above: you can't extrapolate from this into the future.

In investing, hindsight is a siren song that leads to the compulsive urge to

quantitatively extrapolate. The temptation is powerful, and all must be vigilant against falling for it. For example, in the late 90s, the Motley Fool (an investing service anchored in the value investing philosophy) developed something called the "Foolish Four Screen" [Fool(1999)]. It was a quantitative filter of the market, which produced four candidate stocks out of the Dow Jones Industrial Average (DJIA). There was a programmatic investment method you were supposed to follow based on these stocks over time, in order to profit handsomely into the future.

Of course, this quantitative screen abruptly stopped working around the year 2000. Why? Because it had been derived based on retrospective analysis of a random fractal (the chart of the DJIA backwards through the 90s). You cannot project such things into the future.

I am sure the Fool will never make this mistake again, and stick with its value investing moorings.[1] But this certainly illustrates how no one is immune to the temptation.

4.1 Why Mutual Fund Managers Behave Like Random Fractal Market Assets

If value investors can show consistent, fantastic returns over a lifetime, why don't mutual fund managers simply adopt this strategy? If they did, the best fund managers would be the best value investors. Conversely, we should be able to pick the best value investors by picking the top fund managers, and assuming they continue this methodology into the future, bring ourselves fortune by sending them our money immediately.

To some extent, some of the historically best fund managers *have* been value investors (for example, Peter Lynch). But in fact, this is rarely *allowed* to happen for a number of reasons:

1. The larger a fund gets, the more restrictions there are on how it can invest its capital.

2. The more successful a fund gets, the larger it gets. The most successful funds have to stay closed and small, which limits the amount the general public can benefit from them.

3. Funds must do essentially stupid things to show quarterly and annual profits for the investors of their parent companies, their panicky fund clients, and to satisfy the tax man.

4. The mutual fund industry is highly-structured, corporate and insular, with "inbred" mindsets and negative reinforcement for innovation. See Appendix A for more on how this dooms the mutual fund crowd to failure.

[1] I think The Motley Fool is great, but they should have stuck to the original spirit of the Foolish Four Screen—theoretically illustrating how a dumb quantitative investment plan could beat expensively-managed mutual funds in a retrospective analysis—and heavily discouraged investors from actually *executing* the method.

Peter Lynch's fund, Magellan, was closed. When Lynch became acknowledged as smashing success, instead of opening his own fund, he quit while he was ahead. Others open their own funds, and out of greed, capitalize on their fame by taking in as much money as people will give. This leads to more restrictions on how they invest, which probably makes their future performance even *more likely* to be worse than their past performance.

Because of all of these effects, mutual funds basically have the function of "churning;" taking in money and earning commissions, not winning on average, but also not seriously losing and disappointing customers.[2] This causes mutual fund managers behave largely based on quantitative prediction and act with asset protection as the main goal. This ultimately leads their performance to have the same random fractal history as the wider market.

4.2 Why Index Funds Work

"Index funds" are either exchange-traded assets (ETFs) or mutual-fund-like accounts which mirror the composition of some market index. A market index is simply a list of stocks or other market equities. Examples are the S&P500, The Dow Jones Industrial Average, the Russel 5000, and so forth. An index fund consists of investment units that "contain" fractions of all of the stocks in the corresponding index, weighted by market capitalization.

It is fairly well established that index funds are better investments than mutual funds, in part due to the near-lack of management fees compared to actively-managed mutual funds. But if what I said above about random fractal behavior is true, how can index funds be a profitable investment over time? More specifically, how can we justify projecting forward the past success of index funds?

We can do this because such funds effectively choose the top n (some arbitrary number) companies in some sector or market, not adding them until they are clearly a success, and not removing them until they are clearly a failure. In essence, this removes all but the tiniest bit of speculation. On top of this, the fund is massively diversified, and costs little to manage (because the entry and exit criteria are so well-defined).

As a result, index funds (to varying extents) mirror the fact that over time, the sum of all human investment activity produces wealth. This is why the economy keeps growing reliably in stable capitalism, and why our standard of living inexorably increases.

Index funds are simply a way to tap into this effect.[3] Value investing based on more discriminating analysis of stocks can yield drastically higher returns (10-20% annualized versus 8-11%), but this requires much more work to attain.

[2] I believe it is basically criminal for the government to quasi-force citizens to place their retirement in such vehicles, by the rules of IRAs and things like HSAs. Of course, as we well know, the government has no qualms about throwing favors the way of its friends in Big Finance.

[3] Or you can sit back and let your standard of living rise. Note that this can happen even if real wages fall somewhat; investment activity gradually lowers the price of goods and services, and introduces entirely new ones that create new kinds of value.

However, for short-term investing, index funds are a bad idea. Once you "subtract out" the gradual increase trendline from the charts, all that is left is volatility—the same random fractal shape you'll find in all market assets. Don't put any money into an index fund that you think you'll need in the near, or semi-near future.

5 Conclusion

It's fascinating how intuition switches from value investing (which you do in everyday life, when you try to buy goods and services *below* what you think they are worth) to quantitative prediction in the presence of charting and investing tools. These tools seem to feed the superstition that the market has smooth, mathematical predictability. They, and those who shill them, promise to make investing easier than doing real work—having to actually "get out there" and determine how much things are worth in the real world. But this is a promise that cannot be kept, and is why quantitative prediction is bad news.

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APPENDIX

A The Participation Effect

As argued in the body of this paper, market prices behave nothing like the kind of mathematical artifacts—an analytic curve or predictable series—that people intuitively treat them as. However, in this section, I will explain how the situation is much worse for would-be quantitative prognosticators than they might believe, even if they accept my point about random fractal behavior.

The situation is worse because a normative interaction with the market *isn't even really mathematical*. In other words, if you want to make a projection and then act on it, i.e., buy into the market, *you begin changing the market*.

You can analyze the history of an asset or fund's price all you want. The past, as a series of disjoint price points, can at least be treated mathematically and statistically (though not at all in the way smooth function fans would hope). But once you begin participating in the market, you begin altering the present, which alters the future.

This is easy to see: when you decide to buy an asset, you increase the demand for it, which raises the price. The more buyers there are, the smaller this effect is. But the larger your order is, the larger this effect is. And the fewer the sellers, the larger the effect as well.

Even worse, a large number of people acting on the same information you have (and there will be many of them) will multiply the impact of your participation. Via this effect, spikes in stocks when analysts change ratings, research services issue reports, SEC filings and company announcements are released, and other external events which bear on the fundamentals of a security, are well known to cause large moves in the price. People treat these situations as if the information itself is changing the price,[4] but really the price is just being changed by a large number of people just like yourself, acting on the same information.

So you can't harvest the "fruits" of market research without participating in the market. Yet the whole point of quantitative-style research is to profit from finding (relatively) simple mathematical patterns. Unfortunately, actioning this information inevitably changes the market, and thus any simple, quantitative approach to investing becomes its own undoing. Even if, out of sheer luck, a method were to theoretically remain profitable past its point of disclosure, its growing acceptance by investors will change the market such that it becomes a loser. In essence, the "trick becomes priced-in."

In fact, this can happen even if the number of "users" of the method remains small or singular: all that matters is that the money riding on the method grow relatively large—which greed basically guarantees.

In sum, markets are only mathematical constructs *descriptively*, not *normatively*. To paraphrase Benjamin Graham, you can't have prediction by playing

[4] Perhaps the conceptualization is of the price as some objective indicator, set from "outside" by some god-like entity. As usual, feelings and intuition are your enemy in investing.

the numbers; the best you can have is protection.