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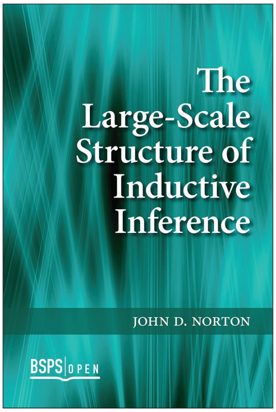

THE LARGE-SCALE STRUCTURE OF INDUCTIVE INFERENCE

John D. Norton

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Stock Market Prediction: When Inductive Logics Compete

1. Introduction

This chapter continues the investigations of Chapters 4 and 13 of the possibility that a single body of evidence might support competing theories equally well. That possibility is precluded, I argued, by an instability in the competition among rival theories. As long as the evidence is pursued sufficiently, that instability will lead to one theory prevailing over its rival. A small advantage gained from evidence by one theory amplifies its inductive powers at the expense of the rival. This amplification leads to an acceleration of the gains of that theory against its rival and speeds the latter's demise. This process can be completed quickly. The competition between dowsers and their skeptics in the previous chapter was exceptional in its slow pace. The stability of our mature sciences arises from the repeated elimination of rivals by this process. Many outcomes of this process fill most of our present science.

This chapter provides an illustration, occurring now, of an otherwise rarer and enduring competition of theories and their associated inductive logics. The competition has endured over decades and shows no sign of a speedy resolution. It arises through efforts to predict the changes in prices of stocks in the stock market. The competition is relatively easy to assess since the predictions are generally unambiguous and their successes or failures soon evident. Either the stock price went up as predicted, or it did not.

I will describe four systems of prediction. Each is currently in vogue, and each has a history extending over many decades. Each, in effect, is an inductive logic, for each uses past stock performance and related facts to discern which among many future possibilities are more likely. The four systems to be discussed are

- fundamental analysis;
- technical analysis;
- random walk/efficient market analysis; and
- fractal/scale free analysis.

They are sketched in Section 2 below. Since each of these systems has spawned evolving research programs of great complexity, a rudimentary sketch of each is all that is possible here. Each sketch indicates the ideas that motivated the system and its founding hypothesis in its simplest and original form. That, however, will be sufficient for my purposes here. Such sketches provide enough to illustrate the differences between the systems and the dynamics of the competition between them.[1] The mutual incompatibility of the different systems is widely recognized and manifests in repeated attempts by proponents of each system to impugn the others. In Section 3, I collect a representative sample of such cross-system criticism. For my purposes, the important point is that the criticism focuses on proposing facts troublesome for the competition. This is how the material theory of induction dictates that differences among systems are to be resolved — by further factual investigation. A concluding Section 4 summarizes general features of the competition and how the factual investigations proposed could drive the field toward a single inductive logic if only they were pursued.

2. The Systems

Multiple systems of inductive logic are possible, temporarily at least. This is a natural artifact of how these systems are constructed. Each is based on founding propositions that warrant the logic's inferences. We shall see in the examples of stock market prediction below that these founding propositions are introduced initially as hypotheses without full inductive support. The expectation of proponents of each system is that this support will accrue

1 For an engaging historical survey of the development of these systems, written by a philosopher of science, see Weatherall (2013).

eventually. Until this happens, the systems will remain legitimately in conflict while proponents of each seek the strong inductive support needed.

2.1. Fundamental Analysis

This venerable approach is based on a simple idea. Each stock, it is supposed, has an intrinsic value. Often there will be discrepancies between the market price of the stock and its value. These discrepancies will not last. If you can identify a stock whose price is well below its intrinsic value, then it can be purchased with the confidence that the price will rise eventually. Correspondingly, a stock whose price is well above its intrinsic value would be a poor long-term investment since its price will fall eventually. The previous two sentences are predictions inductively supported by the founding

> *Hypothesis of fundamental analysis*. Each stock has an intrinsic value. Discrepancies between the intrinsic value and the market price of a stock will be removed eventually by price moves.

This system has a rich pedigree. The work widely known as the "bible of value investing"[2] is Graham and Dodd (2013). It was first published in 1934 and is now in its sixth edition. In his preface to the latest edition, the legendary investor Warren Buffett endorsed the volume and its approach:

> . . . I studied from *Security Analysis* while I was at Columbia University in 1950 and 1951, when I had the extraordinary good luck to have Ben Graham and Dave Dodd as teachers. Together, the book and the men changed my life.
>
> On the utilitarian side, what I learned then became the bedrock upon which all of my investment and business decisions have been built. . . . (2013, xi)

There is considerably more, of course, to fundamental analysis. Graham and Dodd is a work of 766 pages. Perhaps the most delicate issue is the determination of the intrinsic value of a stock. It cannot be merely the market price on pain of trivializing the whole system of analysis. One important element will be the dividends paid by the stock. Others include less tangible judgments of the stability of the stock's business model and its management's acumen and abilities.

2 So reported by Seth Klarman in his preface to Graham and Dodd (2013, xiii).

Fundamentalists make their predictions on the basis of an exhaustive examination of companies behind the stock. In this aspect, fundamental analysis employs a far larger body of evidence than the three remaining approaches discussed below. These latter approaches make their predictions solely on the basis of the history of past stock prices and volumes of trades.

2.2. Technical Analysis ("Chartists")

Technical analysis starts with an observation that can be made by any casual observer of a chart of stock prices over time: the line tracing the prices exhibits all sorts of interesting patterns, some of which appear to be repeated. The core supposition made by technical analysts — "chartists" — is that these patterns are sometimes signals that, properly interpreted, reveal to traders subsequent moves in stock prices. This type of analysis goes back to Charles Dow in the late nineteenth century. This is the same Dow of the Dow Jones Industrial Average. The approach has been refined by many hands. A recent, authoritative exposition is Edwards, Magee, and Bassetti (2019), the eleventh edition of a work first published in 1948.[3]

There are many suppositions underlying that approach. The editor and reviser of the seventh edition attributes to John Magee three principles (Edwards, Magee, and Bassetti 2019, xxxix):

1. Stock prices tend to move in trends.
2. Volume goes with the trends.
3. A trend, once established, tends to continue in force.

A primary goal of technical analysis is the identification in the charts of the signals indicating a reversal of a trend. These signals appear in a bewildering array of patterns in the charts, which are given suggestive names such as "head and shoulders," "symmetrical triangles," "the diamond," and many more.

The existence of these signaling formations is attributed to the behavior of traders reacting to shifts in the market; this behavior, in turn, is explicated by an understanding of the traders' psychology. A simple example is the existence of support and resistance levels, which appear as plateaus of constant price with time in the charts. A support arises when a surge in purchasing

3 Another version of technical analysis is the Elliot wave theory, popularized by Frost and Prechter (2017). It asserts that trader psychology produces nestled waves whose compound action comprises the movements of prices in the market.

forms a plateau that halts a downward trend in prices. A resistance arises when a surge in selling forms a plateau that halts a rising trend in prices.

Following the analysis of Edwards, Magee, and Bassetti (2019, Chapter 13), support and resistance will arise at price levels where, in the past, there was a larger amount of trading. The reason lies with the psychology of the traders involved in these earlier trades. For example, traders might purchase stock at some price level, confident in its price rising. If, instead, the price rises and falls, then traders who have continued to hold the stock might lose confidence in their purchase. When the price rises again and passes through the price at which these traders originally purchased the stock, they would be tempted to sell since then they would have lost nothing on the trade other than the transaction cost. The resulting surge in selling would flood the market and temporarily suppress further price rises. That is, the price would be a resistance level. An inversion of this process could convert the same price level into a support level. If instead the traders become more confident in the wisdom of the purchase, then they might regret not initially purchasing more at the original price. They might be inclined to buy more of the stock when it falls in price to that original level. Then the surge in purchasing forms a support level.

A more elaborate pattern, prominent in technical analysis, is head and shoulders. It consists of three peaks in succession in the charts. In its most characteristic form, the first and third peaks are of the same height, and the second peak is higher. The overall shape is loosely like the silhouette of a person's head and shoulders. Its appearance, we are told by Edwards, Magee, and Bassetti (2019, 44) is common, and it is, they assure us, "by all odds, the most reliable of the Major Reversal Patterns." That is, we can be confident that the stock price will fall once this pattern arises. Their confidence is so high that they later report that, since

> The odds are so overwhelmingly in favor of the downtrend continuing once a Head-and-Shoulders Formation has been confirmed, it pays to believe the evidence of the chart no matter how much it may appear to be out of accord with the prevailing news or market psychology. (48)

As with support and resistance, this head and shoulders formation does not arise by chance. It is a product of the psychology of traders. Edwards, Magee, and Bassetti (2019, 43–44) describe a plausible scenario in which the formation would occur. They imagine a well-financed coterie that has purchased some stock heavily. When it has risen to the price at which they plan to sell, they proceed to sell their holdings hesitantly so as not to precipitate a collapse in the stock's price. In their telling of the scenario, the cautious stopping and starting of the selling happen in just the right way to produce the head and shoulders pattern.

The volume proceeds in this fashion of identifying a prodigious repertoire of patterns for traders to seek and use as signals of reversals in prices. Of course, none of the patterns is infallible. Every few pages, we are warned of "false moves" or "false signals" confounding the technical indicators. The hypothesis that warrants the inferences of this mode of analysis can be summarized as the

> *Hypothesis of technical analysis*. The psychology of market traders leads to trading behavior that imprints distinctive patterns on the changes in time of prices and volumes. The unique association of the earlier and later part of the pattern is strong enough that the presence of the former predicts the coming of the latter.

2.3. Random Walks

The two analytical systems reviewed so far are optimistic. If traders use the right system, each system maintains, then their predictions can lead them to profitable trading. Another approach is pessimistic. Traders, this approach says, are engaged in fierce competition with one another. Any usable indication of a market move is seized and exploited to the full. This happens so rapidly that any actionable indication has already been anticipated, and the move that it foretold is already built into the present price of a stock, at least as far as ordinary investors are concerned. Chance alone governs price movements. It is just self-deception to think that one can beat the averages of market behavior by sophisticated techniques of prediction. The best that one can do is to follow a "buy and hold" strategy that minimizes trading expenses and lets one's fortunes rise with the market as a whole.

Here is how Paul Samuelson (1965, 41) put it, posing it as an enigma that introduced a famous paper:

> "In competitive markets, there is a buyer for every seller. If one could be sure that a price will rise, it would have already risen." Arguments like this are used to deduce that competitive prices must display price changes over time, [formula], that perform a random walk with no predictable bias.

The mathematically precise statement of this form of predictive pessimism is the random walk model. It asserts that stock prices meander in a manner akin to the process that Einstein predicted in 1905 for small particles suspended in a liquid. These small particles are affected on all sides by many fluid molecules. The accumulated effect of many of these uncorrelated collisions is the jiggling known as Brownian motion. It is the best-known example in science of a random walk. The proposal is that stock market prices execute a random walk about their mean values. Most importantly, whether the stock will rise or fall momentarily is statistically independent of what it did moments before.

The random walk hypothesis for markets was first proposed by Bachelier (1900) prior to Einstein's work of 1905. A more recent version is elaborated in Fama (1965). The conditions needed for prices to exhibit a random walk are well known. Drawing from Fama (40–41), they are the

> *Hypothesis of the random walk*. Price changes are governed by a probability distribution with a finite mean and variance, and successive price changes are probabilistically independent.

The most significant predictions supported by the random walk model are negative. The best that one can do predictively is to determine the probability distribution of price changes. An examination of the past history of changes in prices, no matter how thorough and extensive, can provide nothing more. It follows that all of the indicators of technical analysis are predictively useless.

Although the random walk model supports few positive predictions, one has proven to be important. The conditions above for a random walk are sufficient to allow the application of the central limit theorem of probability theory to the accumulation of many price changes. That theorem tells us that, if we sum sufficiently many smaller price changes, then the resulting accumulated price change conforms to a Gaussian or normal distribution. Once one knows the standard deviation "σ" of the distribution, the range of probability changes in prices is well circumscribed. They will mass around the mean: 95.4% will lie on average within two standard deviations of the mean. The probability of larger changes diminishes exponentially since the tail of the normal deviation is exponentially thin. Deviations of six sigma, "6σ," or more are vastly improbable. They arise with a probability of about 2×10^{-9}. That is, they occur on average once in roughly 500 million changes.[4]

2.4. The Efficient Market Hypothesis

The random walk hypothesis is customarily coupled with what is known as the "efficient market hypothesis." It is the idea sketched above that any usable indication of future price changes has already been reflected fully in the present price. Markets are efficient at exploiting all usable indications immediately so that none is left for ordinary investors to exploit. The efficient market hypothesis is commonly taken to be the grounding of the random walk model. We see it in Samuelson's enigma above. Burton Malkiel (2015), in his successful popularization *Random Walk down Wall Street*, writes favorably (in the preface) of the efficient market hypothesis. However, he also portrays the hypothesis as an "obfuscation" (26) of the random walk hypothesis deployed by academics who attempt to parry critics of the random walk hypothesis.

Malkiel's hesitation is well justified, for the efficient market hypothesis is both imprecisely delimited and weaker logically than the random walk hypothesis. It cannot, by itself, sustain the random walk hypothesis. A significant imprecision lies in a failure to specify just which sorts of information can count as an indication of future price changes. Fama (1970, 383) identifies three candidates. If the information is merely that of the past history of prices, then we have the "weak" form of the hypothesis. If the information includes all publicly available information, then we have the "semi-strong" form. Finally, the "strong" form applies when some monopolistic groups have access to all information relevant to price changes. Fama seeks (384) to give the hypothesis more precise expression in terms of the probabilistic expectations of prices over time. Roughly speaking, it asserts that the expected price of a security at a later time rises just by the increase expected with the best current information. It is immediately clear, as Fama shows (386–87), that a

4 You would be correct to wonder whether this prediction conforms to the stock market's history of rarer but memorable crashes. I will take up this issue in the next section.

condition on probabilistic expectations is weaker than the random walk hypothesis, for this latter hypothesis concerns the full probability distributions and not just their expectations. To his critique, I add that the efficient market hypothesis, as commonly stated, is not necessarily a probabilistic hypothesis at all. It can be expressed for changes, stochastic or otherwise, not governed by a probability distribution.

These last considerations show that an efficient market is not sufficient to produce a random walk. It is also not necessary, for a random walk could also arise if traders were maximally inept and merely traded on idiosyncratic whims.

2.5. Mandelbrot's Fractals

The core supposition of this approach is that the charts recording changes in prices are self-similar under changes of time scale. The program of research associated with it is inseparable from the work of Benoit Mandelbrot, its chief architect and proponent. He is fond of telling heroic tales of his discovery:

> . . . I conceived in the late fifties a tool that was already mentioned, but deserves elaboration. I concluded that much in economics is *self-affine*; a simpler word is *scaling*. This notion is most important, and also most visual (hence closest to being self-explanatory), in the context of the financial charts. Folklore asserts that "all charts look the same." For example, to inspect a chart from close by, then far away, take the whole and diverse pieces of it, and resize each to the same horizontal format known to photographers as "landscape." Two renormalized charts are never identical, of course, but the folklore asserts that they do not differ in kind. The scholarly term for "resize" is to "renormalize" by performing an "affinity," which motivated me in 1977 to coin the term "self-affinity." . . . The scholarly term for "to look alike" is "to remain statistically invariant by dilation or reduction." (1997, 5–6; Mandelbrot's emphasis)

Self-similarity is the defining characteristic of fractal curves, such as the Koch snowflake. Each part is made of smaller parts that are scaled-down versions of the larger part and so on at all levels. Thus, that a curve is self-similar is a powerful constraint. A casual reader, however, might overlook that self-similarity is not quite so restrictive in the financial application. As the remark above allows, the similarity is not exact, as with the Koch snowflake. It is only statistical: that is, there is a similarity in the probabilistic distributions only, not the curve's specific shapes, which means that the curves merely "look alike" at different scales.

We best capture the founding hypothesis by quoting what Mandelbrot calls the "property assumed as 'axiom'" (1997, 2) for him, a collection of his papers in fractal finance:

> *Hypothesis of fractal finance*. "Starting from the rules that govern the variability of price at a certain scale of time, higher-frequency and lower-frequency variation is governed by the same rules, but acting faster or more slowly."

Its implementation is straightforward. Consider the probabilistic distribution of price changes over one day. That distribution is the same distribution that governs prices changes accumulated over a month and again those accumulated over a year. Since the overall magnitude of changes in the periods of a day, a month, and a year is different, we must rescale linearly the distribution in moving between these time periods so that the overall magnitudes align and a sameness of probabilistic distribution is recovered. Here "sameness" means "same analytical formula."

As it happens, just this form of self-similarity is already manifested in the random walk model. Price changes over a large interval of time are just the sums of the changes over the smaller component intervals of time. If price changes in small intervals of time are independent and normally distributed with finite means and variances, then their distribution over the summed time interval will also be normal but with a mean and a variance each of which is the sum of the means and the variances of the distributions in the small time intervals. These distributions scale in the sense that we can map any normal distribution into any other by suitable linear transformation of its variables.

As noted above, the central limit theorem of probability theory tells us that this scaling behavior eventually will emerge as the limiting behavior on sufficiently large time scales even when the probability distributions over the smaller time intervals are not normal. It will happen as long as the probability distributions over the smaller time intervals are independent and have finite means and variances (and, informally speaking, no one time interval makes a disproportionately large contribution to the sum).

The essential observation that Mandelbrot added to this already existing self-similarity is that a Gaussian or normally distributed random walk is not the only distribution satisfying self-similarity. His early paper (1963) outlined a generalization of this self-scaling behavior that arises when the distributions of price changes in the small time intervals are no longer required to have finite means or variances. The most general class of distributions that exhibits the self-similarity under summation of the distributions Mandelbrot called "stable Paretian." That is, if the distribution of price changes in the smaller time intervals is stable Paretian, then so is the distribution of price changes over the summed time interval. These distributions also sustain a generalized version of the central limit theorem. The theorem is as stated above. However, we can drop the requirement that the component distributions have finite means and variances, but we retain their independence. What we are assured to approach in the limit of large sums is a stable Paretian distribution, which includes normal distributions as a special case. So once again we should expect self-similar behavior to be approached over suitably long time periods.[5]

Mandelbrot's contribution was not the identification of this extended class of distributions and the associated extension of the central limit theorem. As Mandelbrot reported, all of this work was already done by the French mathematician Paul Lévy some forty years earlier. Rather, it was to recognize that the nonnormal members of the Paretian class were better suited empirically to market behavior. As we saw above, the normal distribution makes large jumps in prices extremely improbable. Yet such jumps are common in real markets. The nonnormal members of the distribution are distinctive in having "fat tails." That is, they assign considerably larger probabilities than normal distributions to large deviations from the mean. These deviations are the jumps. More specifically, the nonnormal Paretian distributions over some real variable U all approach asymptotically a simple power law distribution for large U. That is, when U is large, the probability of an outcome u greater than U is well approximated by $P(u) = C\, u^{-\alpha}$, for C a constant and $0 < \alpha < 2$. As the variable u increases, any of these power laws decays toward zero slower than the exponential decay of any normal distribution.

5 For a contemporary development of Mandelbrot's analysis, see Fama (1965). A more recent analysis of the generalized central limit theorem is in Ibe (2013, Chapter 8).

Mandelbrot (1997, 29–30) glosses the "scaling" behavior of this tail distribution by noting that, if we were to learn that U must be at least equal to w, then conditioning the original distribution on this fact yields the same power law distribution but now with an altered constant C. This seems to me a weak expression of the scaling behavior, better captured by the generalized central limit theorem. We can forgive Mandelbrot for not giving more mathematical details in a semi-popular presentation since the details become burdensome rapidly. There is no explicit expression for the Paretian class of distributions. They are best characterized by an explicit formula for the characteristic functions of the distributions.

This introduction of Paretian distributions was the first step in a continuing program of research by Mandelbrot. Subsequent work introduced the possibility of various failures of independence of successive price movements while still retaining the statistics of Paretian distributions with their fat tails.

2.6. Random Walkers and Fractals Converge

The random walk theory and the fractal theory might appear to be distinct systems with different logics. That was the view that Mandelbrot urged. He was already describing his work in 1963 as "a radically new approach to the problem of price variation" (395). There were notable differences between his approach and that of the random walk theory at the outset. Mandelbrot denied two of the basic assumptions of the random walk theory: the finite variance of price changes and the independence of subsequent changes. As far as the actual predictive apparatus is concerned, the use of distributions with infinite variance and fat power law tails comprise the main substance of Mandelbrot's deviation from the traditional random walk theory. The scaling hypothesis by itself is not strong enough to preclude the Gaussian random walk theory. Indeed, the introduction of infinite variances and fat-tailed distributions must be supported by observation of the market prices, and those observations might well suffice without the scaling hypothesis if our goal is merely the compact summary of the data.

Viewed more broadly, the random walk theory and the fractal approach agree far more than they disagree. They share a statistical framework that presumes that prices are probabilistically distributed, that market analysis is the mathematical exploration of these distributions, and that these distributions exhaust what the analyst can know. To a chartist, however, whose methods do not include traditional statistical analysis, the differences between the random walk theory and the fractal approach will appear to be mere fine-tuning of details in an analysis remote and alien to them.

More significant for my purposes here, these differences are diminishing. The approaches are converging. In the evolving literature on random walks, empirical investigation is to decide whether the variances are finite and whether there are failures of independence. It now seems to be well established that independence does fail. That recognition is reflected in the provocative title of *A Non-Random Walk down Wall Street* (Lo and MacKinlay 1999). The title is hyperbolic since it turns out that the failures of independence are so slight as not to be serviceable as predictive tools for ordinary traders.

The mainstream of statistical analysts seems to regard Mandelbrot's contribution as mere refinement, as is apparent from the papers collected in Lo and MacKinlay (1999). The word *fractal* appears once (15), and Mandelbrot's work is addressed but treated as an interesting proposal among others for extensions of the probability distributions and dependencies of the mainstream analysis. The word *fractal* and the name Mandelbrot do not appear in Malkiel (2015).

Mandelbrot, for his part, accepts the core lesson of the random walk theory, the unpredictability of price changes. However, he expands this predictive pessimism with a warning that price changes might be far larger than the traditional random walker expects:

> . . . I agree with the orthodox economist that stock prices are probably not predictable in any useful sense of the term. But the risk certainly does follow patterns that can be expressed mathematically and can be modeled on a computer. Thus, my research could help people avoid losing as much money as they do, through foolhardy underestimation of the risk of ruin.[6] (Mandelbrot and Hudson 2004, 6)

3. The Systems Compete

The competition among these systems is unsustainable in the longer term if factual investigations continue and the full import of evidence is respected. The competition might be resolved gently if systems in competition migrate

6 A similar remark is in Mandelbrot (1997, 9).

toward one another. This gentle resolution has brought the random walk theory and fractal analysis into sufficient agreement that they can be regarded as one system. However, if the proponents of competing systems remain intransigent, then, I have argued, a thorough factual investigation will lead at most to one ascending while the others fail.

Proponents of each system do recognize the threat posed by the other systems and have put some effort into impugning their competitors. Here I will collect criticisms levied by proponents of each system against competing systems. The main point for my purposes is that the criticisms all depend on proposing facts whose truth would undermine the competitors' theories. They are most damaging when the proposed facts directly contradict the founding hypotheses of each system. A threat to these founding hypotheses is a threat to the inductive logic and the predictive capacity of the associated view.

This battle of the foundational facts makes clear one of the principal points of this chapter: that the conflict among the systems is to be resolved by factual investigation, as opposed to higher-level examination of abstract principles of inductive inference. Were the facts proposed below by various proponents to be investigated thoroughly and a final decision made on each, that would suffice to leave viable at most one of the systems. The path to this resolution is open. Whether it is taken depends on many factors that go beyond the inductive logic. Is there sufficient motivation by investigators to carry out the requisite studies thoroughly enough to achieve inescapable results? Will proponents of an impugned system accept the results? The persistence of the competing programs indicates that these factors have slowed or even stalled progress toward the final decision.

Below is a sample of the threats mounted against each system.

3.1. Against Fundamental Analysis

Malkiel, the most visible proponent of random walk theory, lists three problems for fundamental analysis:

> Despite its plausibility and scientific appearance, there are three potential flaws in this type of analysis.
>
> *First*, the information and analysis may be incorrect.
>
> *Second*, the security analyst's estimate of "value" may be faulty.

> *Third*, the market may not correct its "mistake," and the stock price may not converge to its value estimate. (2015, 128–29; my emphasis)

Malkiel proceeds to elaborate each. Most striking is his disparaging of the very idea of value:

> It is virtually impossible to translate the specific estimates of growth into a single estimate of intrinsic value. Indeed, attempts to obtain a measure of fundamental value may be an unrewarding search for a will-o'-the-wisp. (129)

Edwards, Magee, and Bassetti, the authoritative source in technical analysis, level similar criticism against fundamental analysis. They reiterate Malkiel's concern about poor information: "The bulk of the statistics the fundamentalists study are past history, already out of date and sterile because the market is not interested in the past or even in the present" (2019, 4). Using an examination of companies listed in the Dow Jones Industrial Average, they also argue that high earnings are a poor indicator of which stock prices will grow most (6). Next they assail the idea of a practically accessible notion of value, urging that ". . . it is futile to assign an intrinsic value to a stock certificate" (4). The claim is reinforced by recounting wild gyrations in the price of a share of US Steel over nearly two decades, from 1929 to 1947. Finally, they doubt that price movements are connected with the factual bases used by fundamentalists to determine value. They assert that "the [fundamental] analyst assumes causality between external events and market movements, a concept which is almost certainly false" (6). Mandelbrot's (1997, 8) critique echoes all of these concerns: "In the real world, causes are usually obscure. Critical information is often unknown or unknowable. . . ."

This combined critique assails the essential elements of the founding hypothesis of fundamental analysis. Intrinsic value is not in practice ascertainable reliably, and market dynamics might not or will not drive prices toward intrinsic value.

The claims of this critique are factual matters. The truth of the founding hypothesis of fundamental analysis can be established empirically. All that fundamental analysts need to display is a successful record of identifying intrinsic values toward which stock prices eventually converge.

3.2. Against Technical Analysis

Of all the approaches, technical analysis has been subject to the most severe criticism, at times bordering on derision.[7] Two factors draw this unflattering appraisal. First, to anyone with a modicum of statistical sophistication, the methods used to ascertain the chartists' patterns are woefully naive. It is all too easy to glance at randomness and see order. We easily see faces in the clouds. In a preface to Edwards, Magee, and Bassetti, Richard McDermott, president of John Magee, Inc., reports the great man's response to this concern:

> To the random walker, who once confronted John [Magee] with the statement that there was no predictable behavior on Wall Street, John's reply was classic. He said, "You fellows rely too heavily on your computers. The best computer ever designed is still the human brain. Theoreticians try to simulate stock market behavior, and, failing to do so with any degree of predictability, declare that a journey through the stock market is a random walk. Isn't it equally possible that the programs simply aren't sensitive enough or the computers strong enough to successfully simulate the thought process of the human brain?" Then John would walk over to his bin of charts, pull out a favorite, and show it to the random walker. There it was — spike up, heavy volume; consolidation, light volume; spike up again, heavy volume. A third time. A fourth time. A beautifully symmetrical chart, moving ahead in a well-defined trend channel, volume moving with price. "Do you really believe that these patterns are random?" John would ask, already knowing the answer. (2019, xxxv)

We would normally pass in silence over such an abysmal display of ignorance of the basics of statistical analysis. However, the second factor that encourages circulation of the unflattering appraisal is that the methods of technical analysis are pervasive in the financial world. Everywhere we find charts annotated in the language of support and resistance levels, breakouts, and more. There is a pretense of learned insight that rests, in practice, on novice

7 Ridicule is a staple in the popular literature. See, for example, Chokkavelu (2010), which opens with the quotation "Stupid is as stupid does" (*Forrest Gump*).

statistical blunders. Yet these instruments are used routinely to make decisions affecting the financial fates of many people. Thus, the long-standing derision is well earned. Long ago, in their original text, Graham and Dodd (1934, 608) reported "many [unnamed] sceptics" who dismiss the analysis as "akin to astrology or necromancy." Mandelbrot (1997, 9) had no need for anonymity and labeled technical analysis "financial astrology."

A footnote in Graham and Dodd's original text also reports one of the earliest versions that I have found of a much-repeated rebuke. The idea is that we can fabricate charts using randomizers that now spuriously manifest the patterns of the technical analysts but without any predictive import. They write that,

> Apropos of this attitude, we refer to a statement made by Frederick R. Macaulay at a meeting of the American Statistical Association in 1925, to the effect that he had plotted the results of tossing a coin several thousand times (heads = "one point up"; tails = "one point down") and had thereby obtained a graph resembling in all respects the typical stock chart — with resistance points, trend lines, double tops, areas of accumulation, etc. Since this graph could not possibly hold any clue as to the future sequence of heads or tails, there was a rather strong inference that stock charts are equally valueless. Mr. Macaulay's remarks were summarized in *Journal of the American Statistical Association*, Vol. 20, p. 248, June 1925.[8] (1934, 608)

The rebuke appears often in later literature. Malkiel (2015, 137–38) reports asking his students to construct such a chart by coin flipping.

Entertaining as such gimmicks might be, they do not really demonstrate the failure of technical analysis. If we are to hold the chartists to a high statistical standard, then we should also apply it to ourselves. To conclude that, *on a superficial scan*, random data might manifest the same patterns as the chartists does not prove them wrong. More cautious analysis is needed. Arditti and McCullough (1978) found that technical analysts could not pick apart real

8 The journal article cited is an anonymous report of an April 17, 1925, dinner meeting of the American Statistical Association. Graham and Dodd must be reporting from another source, perhaps their own attendance, since the journal text is briefer and uses dice, not coin tosses, as the randomizers.

from randomly generated charts beyond chance levels in a well-constructed test. However, Hasanhodzic, Lo, and Viola (2010) devised a game in which participants sought to pick real from fabricated charts. The players were given immediate feedback on the correctness of their judgments. The training was effective. They quickly learned to pick the real from the fabricated charts.

All that the examination of fabricated charts can do is cast doubt on the methods that chartists use to arrive at their results. A poor method can still yield a correct result. It might just be that the psychology of traders does imprint identifiable patterns on the charts, as the founding hypothesis asserts. The decisive question to answer is whether the methods work. Here Graham and Dodd (1934, 609) had already leveled a two-part critique. As a historical matter, they reported, the chartists had failed to find a method of prediction that works. "There is no generally known method of chart reading which has been continuously successful for a long period of time." This historical report was coupled with a more principled critique: there can be no such method since it would be self-defeating: "If it were known, it would be speedily adopted by numberless traders. This very following would bring its usefulness to an end."

Here the fundamentalists, Graham and Dodd, offered the same critique as that given later by the random walk proponent, Malkiel. He reported empirical studies showing that the chartists' patterns lack predictive power (e.g., 2015, 114). His principal criticism, however, was the same efficient-market argument as that offered by Graham and Dodd: the chartists' methods cannot work since they undermine themselves.

> Any successful technical scheme must ultimately be self-defeating. The moment I realize that prices will be higher after New Year's Day than they are before Christmas, I will start buying before Christmas ever comes around. If people know a stock will go up tomorrow, you can be sure it will go up today. Any regularity in the stock market that can be discovered and acted upon profitably is bound to destroy itself. This is the fundamental reason why I am convinced that no one will be successful in using technical methods to get above-average returns in the stock market. (Malkiel 2015, 156–57)

As before, the decision on the cogency of the chartists' methods is an empirical matter to be decided by investigations of the market. In principle, arguments such as those against technical analysis are impressive until empirical investigations show their conclusions to be false. Only then do we realize the fragility of assumptions made tacitly in the arguments. Aronson (2007) makes a sustained plea for technical analysts to hold their methods to the standards of routine statistical analysis. Perhaps Graham and Dodd and Malkiel were correct that enough has been done to refute technical analysis. There are dissenters. Lorenzoni et al. (2007) claim that statistical analysis does reveal statistically significant information in two of three patterns: triangle, rectangle, and head and shoulders.

3.3. Against Random Walks

Here I shall construe the random walk theory most broadly as including the possibility of small failures of independence and of distributions with infinite variances. This expanded version includes Mandelbrot's fractal approach. It still retains the main idea that distinguishes the original random walk theory and fractal analysis from other approaches and draws criticism: markets are sufficiently random as to preclude useful prediction of change in prices beyond the broadest averages.

Although this failure of prediction directly contradicts the technical analysts, there is little in the technical analysts' authoritative volume, Edwards, Magee, and Bassetti (2019), to contradict the random walk theory. We have seen Magee's facile response, reported above by McDermott (2019). Otherwise, "random walk" and "efficient market hypothesis" do not appear in the index or, as far as I can tell, in the text. Aronson (2007, 342–55) lays out an extended assault on the efficient market hypothesis. The approach is to undermine what he takes to be the founding assumptions of the hypothesis. For example, he urges that investors are not rational, that their investing errors are not uncorrelated, that arbitrage need not force prices to rational levels, and more. The weakness of the critique is that Aronson does not properly separate the efficient market hypothesis from the hypothesis of a random walk. However, important for my purposes here is that all of the objections depend on factual matters, such as those just listed, and their truth can be ascertained by empirical investigations.

Buffett gave the authoritative response from the fundamentalists to random walk theory. His extraordinary record of profitable investing alone indicates that an astute analyst can make successful predictions over sustained periods. His "Superinvestors of Graham-and-Doddsville" (1984) makes the case against the impossibility of predicting the market in a direct way. He reports nine successful investment funds that exceeded market averages in their returns by wide margins and did so over long periods. The longest of them was 1956 to 1984.

This behavior contradicts the unpredictability of markets central to the random walk theory. More specifically, when the prices of undervalued stocks eventually rise assuredly to their true values, the sequence of upward changes in prices contradicts the independence or near independence of the price changes hypothesized in random walk theory.

The obvious random walk theorist's response is that, in any large economy with many such funds, there will always be outliers that perform well merely by chance. Buffett goes to some pains to answer this objection. The funds on which he reports were selected prior to their successes. As he puts it, "these winners were all well known to me and pre-identified as superior investors, the most identification occurring over 15 years ago" (1984, 4). Buffett also stresses the many differences between the funds while retaining the major common factor: they all follow the Graham and Dodd policy of investing when prices and values are mismatched. This common factor, we are to believe, is responsible for their successes.

There is also a casual rebuttal of the efficient market hypothesis, memorable because of the credentials of its source:

> I'm convinced that there is much inefficiency in the market. These Graham-and-Doddsville investors have successfully exploited gaps between price and value. When the price of a stock can be influenced by a "herd" on Wall Street with prices set at the margin by the most emotional person, or the greediest person, or the most depressed person, it is hard to argue that the market always prices rationally. In fact market prices are frequently nonsensical. (Buffett 1984, 13)

Once again Buffett's argument is a direct challenge to the founding hypothesis of the random walk theory and its embellished versions. The basis of the challenge is empirical. If it is an empirical fact that a particular sort of investment strategy leads to long-term profits, well in excess of market averages, then the unpredictability of the market has been refuted.

4. Conclusion: The Instability of Competing Systems

Competing systems arise when analysts proceed from different, mutually incompatible hypotheses. The competition should be transient while we await further evidential scrutiny that will decide which, if any, of the hypotheses is well supported. As the full import of the existing evidence and that of new evidence is brought to bear, we have seen two ways that the competition could be resolved.

4.1. The Gentle Way: Convergence

In the gentler way, one or more of the systems in competition alter their founding hypotheses to accommodate evidential pressures. If this process of adaptation proceeds far enough, then competing systems might converge. This convergence has happened in the case of the random walk theory and fractal analysis. While the systems might first appear to be very different, they agree on so much at the outset that convergence was easily attained. Both adopt an essentially probabilistic outlook using the standard statistical methods of analysis. They differ only in smaller matters that can be settled by smaller empirical analysis. Are the variances of the probability distributions of price changes finite or infinite? What are the extent and nature of any probabilistic dependence among successive price changes? Insofar as proponents of the approaches accept the results of empirical studies, and if the statistical approach is viable in the first place, then the convergence was inevitable.

In principle, a convergence of this generalized random walk theory and technical analysis is also possible. It would be inevitable if chartists would heed Aronson's (2007) urging of the use of sound statistical methodology. Either the statistical studies will show a correlation between the head and shoulders formation and a subsequent decline in prices, or they will not. Once both groups of theorists accept these statistical methods, agreement on the efficacy or otherwise of these chartists' signals is inevitable if only the empirical studies are pursued thoroughly. The losing approach then would need to adapt its founding hypotheses accordingly. Or both might adapt to some compromise account containing elements of both original approaches.

4.2. The Severe Way: Elimination

The more severe path to a unique logic arises when proponents of each competing logic are intransigent and refuse to adapt their logic to emerging evidence, for the competition is unstable. Evidence that turns out to support one system's founding hypothesis will strengthen that system while weakening those that disagree with it. A stronger system can infer to still more that strengthens it further while weakening the competition. The process is akin to the instability of a pencil balanced on its tip. Once the pencil starts to fall to one side, the forces pulling it to that side are strengthened, and the fall accelerates.

The competition between random walk theorists and chartists illustrates this instability. The generalized random walk theory depends essentially on the independence or meager dependence of the probability distributions of successive price changes. This meager dependence needs to be demonstrated, in principle, for each stock or each stock sector index. Each success would detract from the prospects of the chartists, whose theories depend essentially on a failure of independence. Their head and shoulders formation can be a reliable indicator of a coming reversal only if there is a strong correlation between it and subsequent price changes.

As this independence is established for more individual stocks or indices, each success provides indirect support for independence among untested stocks or indices. This last inference is supported by a warranting hypothesis that the mechanisms governing price moves are much the same across the market. These successes form a cascade of continuing successes, each amplifying the strength of support of the random walk theory's claims elsewhere. Each also brings the corresponding collapse of the competing chartists' system. This is a cycle of positive reinforcement that would terminate in the elimination of technical analysis.

The reverse process would arise if, instead, chartists were able to demonstrate with statistical rigor the efficacy of one of their formations as a signal for future price movements. Such a success would contradict the very limited dependence among successive price changes that the random walk theory is prepared to accept. The assumption that the mechanisms moving prices are much the same across the market would support an inference that similar signals are possible elsewhere. As their successes mount, the prospects for the limited dependencies allowed by the random walk theory would narrow.

Continuing successes eventually would end in the demise of the random walk theory.

As we saw above, the fundamentalists' challenge to the other systems is laid out most cogently by Buffett (1984). Using the evidence of several successful investment funds, he claims that pursuit of value-price discrepancies led them to purchase stocks whose long-term price gains greatly exceed market averages. He argues that the only common factor among them is their focus on value. He insists that the successful funds dismissed daily price movements as meaningless distractions. If they prove demonstrably to be correct about daily price movements, then the basic supposition of technical analysis would be refuted. If the success of value investing persists and is sustainable under careful statistical analysis, then random walk theorists who respect statistical methods must accept the fundamentalist approach. Conversely, if statistical analysis reveals their successes to be merely the luck of a few, then fundamentalists would have to retreat. With each new report of a successful value investor, the fundamentalist approach would be strengthened, once again under the assumption that the mechanisms moving prices are much the same across the market. The random walk theory would be weakened, for it would be harder to dismiss these successes as mere chance.

4.3. Multiple Systems Are Possible if They Do Not Compete

The processes assuring ascendance of one dominant logic at most arise only when the systems truly conflict. In the earlier chapter, I raised the possibility of multiple systems coexisting if the domains could be divided so that each logic would apply in its partition only. Such a possibility could be realized in principle here. Fundamental analysis draws from a different body of evidence from the other three systems and makes predictions over a longer time span. We might divide the field of stock market prediction into two partitions.

The evidence base for the first is the detailed compilation of facts about all aspects of the companies associated with each stock, and the time scale for predictions is some suitably chosen longer term. Fundamental analysis would apply in this partition.

The evidence base for the second partition is restricted to the past history of stock prices and volumes traded. Predictions would be made over the shorter term. Each of the remaining systems has aspirations in this partition.

Although such a partition is possible in principle, fundamental analysts and those of the other systems do regard themselves as being in competition. Each does seek to impugn the basic suppositions of the others.

4.4. Principle and Practice

The processes sketched above map out how, in principle, suitable empirical investigations can and should dissolve eventually the competition among the logics. Convergence to a single logic, then, awaits only analysts willing to undertake the investigations and proponents of the systems willing to accept the results. In practice, however, the differing systems persist, and there is little hope that this circumstance will change. We can speculate about why this is so. Perhaps the continuing infusion of new traders into the stock market replenishes the pool of novice enthusiasts, well informed on just one system. Perhaps there is too much inertia among proponents of each competing system. The chartists are too wedded to their charts, the random walk theorists are too wedded to their theorems, and the value investors are too wedded to company balance sheets. Whatever the reasons, this persistence reveals little of the applicable inductive logic and more of the contingent social factors.

4.5. Material and Formal Approaches

How can competition among different inductive logics in some domain be resolved? These examples display how a material approach to inductive inference succeeds in answering easily where a purely formal approach cannot. According to the material theory, facts warrant inductive inferences. Hence, a local resolution is possible merely through investigations that establish which are the facts of the domain. Such investigations have been the substance of the dispute among the systems discussed here.

If instead we were to conceive of inductive logics as governed by universally applicable formal schemas, then no such easy resolution would be possible. A dispute over which is the right logic must proceed at the remotest level of generality, separated from any considerations specific to the domain. No such domain-specific considerations can enter, tempting as they would be. To say that this logic is better adapted to this domain and that logic better adapted to that domain is to give up the universal applicability of the formal schemas. It is tacitly to become a material theorist who looks to facts of each domain to decide which inductive logic applies.

For example, a probabilist might argue for the probabilistic methods of random walk theory on the supposition that all uncertainties everywhere are probabilistic. This is a supposition at the highest level of generality that, as I have argued in *The Material Theory of Induction* (Norton 2021), is unsustainable. A more realistic probabilist might argue merely that the sorts of uncertainties in stock prices are factually of a type to which probability theory applies. To do that is just to adopt the core idea of the material theory of induction: facts in the domain warrant the inductive logic applicable.

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