CHAPTER 20

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The Coming Revolution in Marketing Theory

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> Our modern civilization is due to the fact that in the year Galileo died, Newton was born. . . . This one a supreme experimentalist and enough of a mathematician, and that one a supreme mathematician and enough of an experimentalist.
>
> Alfred North Whitehead
> *The First Physical Synthesis*

On the occasion of the seventy-fifth anniversary of the Harvard Business School, we have been asked to examine the impact on marketing of new information technology. There is no doubt in my mind that this new technology will lead to greater precision with which to observe marketing phenomena and greater technological power with which to plan and implement marketing strategy. So expected is this information revolution that *Business Week* for April 25, 1983, claimed a new era for management with "the shrinking of middle management," "computer-run offices and factories," and an accompanying social revolution, "a disenchanted middle class."

For students in the history of science, it is clear that there will be a revolution in marketing, and that the revolution will result from greater precision and technological power, but also that the revolution will come from an unexpected source, mathematical theorists. Just as our understanding of financial strategy changed dramatically with the sudden onslaught of new theory, so too will marketing strategy. Even now at the leading business schools, mathematical theorists are building upon empirical data and questioning the way we view marketing phenomena.

In this essay I hope to persuade you that the revolution is coming. It will be resisted, but it will come. My thesis is not normative, but predictive. I draw this hypothesis partly from published essays on revolutions in science, partly from my experience as an editor and a member of editorial boards for technical marketing journals, partly from some of my own attempts at theory, and partly from my background and training in the physical sciences and engineering. (Curiously, such training is a common cultural bond among the majority of mathematical marketing theorists.)

Throughout this essay I provide examples of marketing theory, mostly based on consumer packaged goods. But you must understand that these are only a modest beginning, creative advancements that signal breakthroughs that will shake the foundations of marketing thought in many areas including durable and industrial products, tactical and strategic decisions, and domestic and international arenas.

Precision

> It merely looked at data, and applied to it neither thought nor imagination—like the ethnocentricists in the Middle Ages who saw with everyday clarity the sun revolving in predictable ellipses around the earth, as opposed to Copernicus who interpreted a more compelling reality, having no more data than they, but a more searching mind.
>
> Theodore Levitt
> *The Globalization of Markets*

> With information available instantly, decisions can be made faster—and with more precision.
>
> *Business Week*
> April 25, 1983

Any consumer goods market researcher worth his salt must today recognize the incredible precision of measurement possible with data collected from automated supermarket checkouts. We can now observe daily, potentially even hourly, responses to price changes, end aisle displays, and other marketing actions. We can record the in-store environment for our products and, of equal importance, our competitors' products. We can track a family over time and across multiple stores. With "split cable," we can add to this data base records of the television advertising the consumer sees and we can experiment with alternative formats and exposure levels. And researchers are still adding to this data base. For example, researchers at the University of Chicago have added information on print advertising exposure and format.[1] This measurement has spawned sophisticated analysis systems. For example, at MIT, Guadagni and Little have developed analytical computer models that use these data to uncover promotion and price elasticities with previously unattainable precision.[2] Using Bell System data bases, AT&T now has a system that can measure the impact of advertising copy at the level of one additional telephone call per year.[3] No longer must we continually live with large measurement error and unobservable outcomes. The outcomes are in plain view and demand explanation. Let us examine the impact of data on science.

Theodore Levitt alludes to the Copernican revolution. In A.D. 146, a Greek philosopher, Ptolemy, postulated that the earth was at the center of the universe and that the sun, the moon, the planets, and the stars rotated around the earth on celestial spheres. Of course, the planets were a bit eccentric, and Ptolemy and subsequent scientists added an amazingly complex set of spheres within spheres to explain deviations from perfection. Within the measurement system of the first fourteen centuries, the Ptolemaic system was sufficient to explain the motions of the heavens. But as measurement improved in the Renaissance, more and more "epicycles" were added to the Ptolemaic model to make it work. The model was in crisis. It had become too complex. Astronomers began to wonder whether there might be a simplicity in celestial motion that was obscured when such motion was interpreted within the complexity of the prevailing Ptolemaic model.

Then, in 1543, Copernicus, in a radical departure from established scientific thought, saw the sun at the center, with the earth revolving around it. The model was now simpler, though Copernicus had to retain "epicycles" in order to have the earth and the planets revolve in spheres.

Copernicus was a genius, but not the first. In the third century B.C., Aristarchus had postulated a sun-centered system. But the measurement capability in his time could not distinguish between the two theories and common belief held the earth to be the center of the universe. After all, it was plain to all observers that falling objects fell downward to seek the center of the universe. Poor Aristarchus; his theory was sound, but without the proper instrumentation, he could not demonstrate its validity. He could only stand accused of impiety.

Even in 1543, measurement was not yet sufficiently accurate to distinguish an earth-centered celestial system from a sun-centered system. But the Ptolemaic model was in crisis and measurement was improving. In 1576, Tycho Brahe persuaded Frederick II to underwrite improved measurement. Brahe spent the next twenty years collecting data he hoped would combine the Copernican system with the Ptolemaic system. He never achieved this synthesis, but "on his deathbed he solemnly confided his system to his celebrated pupil, Kepler, then but 28 years old."[4]

And He Set Forth Laws

> Physics, however, does not consist merely in building up encyclopedic records of the motions of particles. Observations are a beginning, not an end in themselves. From them (as Newton said) we hope to infer laws of motion—generalizations that embrace all motions of a given type.
>
> A. P. French
> *Physics: A New Introductory Course*

> An increasingly rich literature of empirical studies helps resolve these issues by revealing major advertising phenomena that models should encompass.
>
> J. D. C. Little
> "Aggregate Advertising Models: The State of the Art"

Brahe's measurement was the most accurate one the world had ever seen. He became an international celebrity in his own time, entertaining philosophers, theologians, and princes at his observatory. But it remained for young Kepler to unify twenty years of data, to establish the dominance of a sun-centered system, to greatly simplify our understanding of the motion of heavenly bodies, and to spark the mathematical revolution in astronomy. He did it with the following three simple axioms.

1. The planets move in ellipses having the sun at one focus.
2. The line joining the sun to a given planet sweeps out equal areas in equal times.
3. The square of the planet's year, divided by the cube of its mean distance from the sun, is the same for all planets.[5]

From these axioms and analytic geometry, Kepler was able to reproduce Brahe's measurements. It must be remembered that Kepler set out to complete Brahe's unification, but he could not do so if he were to be true to the data. With his genius and his faith in the accuracy of Brahe's measurements, he was able to see simplicity where his contemporaries saw complexity.

Today, on a modest scale in marketing science, such laws are being set forth to synthesize and summarize the chaos of data. I choose as one example, Little's five postulates of advertising response. Before setting forth these laws, let me briefly summarize Little's reasoning.

Little has been studying advertising response for almost twenty years and has published extensively in academically respected journals.[6] But in 1979, he found that "ignorance of advertising response phenomena, inability to make good measurement, and a lack of theory to organize existing knowledge contribute to great waste in advertising. Contradictions abound."[7] Little presents a series of anecdotes to illustrate that managers often implicitly assume contradictory postulates to justify actions, and that hard, quantitative questions, such as "should a 'flight' be half as long and twice as intense?" are often not even asked.

But all is not lost. Advertising research has its Tycho Brahes and a large number of careful empirical studies have been documented. Little reviews the data and synthesizes them with the following five laws.

1. Sales respond dynamically upward and downward to increases and decreases of advertising and frequently do so at different rates.
2. Steady-state response can be concave or S-shaped and will often have positive sales at zero-advertising.
3. Competitive advertising affects sales.
4. The dollar effectiveness of advertising can change over time as the result of changes in media, copy, and other factors.
5. Products sometimes respond to increased advertising with a sales increase that falls off even as advertising is held constant.[8]

Once stated, these laws are self-evident. How could anyone not believe them? What manager would act in a manner that assumes they are false? Yet, in his review of analytic models, Little finds that famous economics models of advertising such as the Vidale-Wolfe and Nerlove-Arrow models are woefully lacking in their ability to be consistent with these laws and that many management science models and managerial actions do little better. Little does not condemn these actions and models; after all, Ptolemy and Copernicus were geniuses, even though their models were later modified. But Little demands that we listen to the data and modify our models if they cannot explain the data.

Little gives us hope. He goes on to show that modifications to the Lanchester model and his own Brandaid model can handle four of the five postulates. He closes on the optimistic note that "in the next 5 to 10 years there will be abundant opportunities for understanding advertising processes better and putting this knowledge to work in improving marketing productivity."[9]

I note that Little's postulates are being resisted; for example, they sparked a lively, productive debate among some of marketing's best scientists at the first marketing science conference, held in March 1983 at the University of Southern California, and the debate is far from over.[10] Furthermore, they are unlikely to be the final word, as researchers challenge, extend, and modify these simple postulates. They are, however, a beginning.

More Precision and Some Thought

> Alas, a few years ago, I should have said "my universe": but now my mind has been opened to higher views of things.
>
> Edwin A. Abbott
> *Flatland*

> It might have remained a toy, but in his hands it created a revolution.
>
> Alfred North Whitehead
> *The First Physical Synthesis*

Little's postulates explain how advertising responds to marketing actions, not why. To complete the revolution we must know why. With "why," we can generalize to new situations and develop creative ways to influence advertising response.

Let's return to Kepler. His laws tell us how planets move, not why. Newton's laws explain why, but before Newton came Galileo. It was obvious to the Greeks and to Galileo's contemporaries that a rock falls faster than a leaf. Surely, heavier objects fall faster. But Galileo thought more deeply and set forth the following "thought experiment":

> Suppose I have two identical balls. Then, by the above law, they must fall at the same rate. But suppose they were linked by some massless invisible string. They weigh twice as much and will fall, perhaps, twice as fast. But this appears to be a contradiction.

Galileo was led to the conclusion that all objects must fall at the same rate and conducted the famous Tower of Pisa experiment to demonstrate his law of gravity. We now believe the deeper truth that the leaf falls more slowly than the rock because of air resistance.

In the epigraph above, Whitehead refers to Galileo and the telescope. Galileo used the telescope to observe the heavens and asked why moving objects such as planets ever stop. "This question must have seemed like sheer effrontry, since anyone could plainly see that rest was the natural state of a body, a state which a body sought to recover as soon as it was put in motion."[11] Galileo insisted that bodies in motion tend to stay in motion. But to do so he had to abstract from reality and study, in his mind's eye, the frictionless plane, an entity that can never really exist. Such abstractions occur throughout science. Ask any chemist about Boyle's law, which defines an "ideal gas," or any electrical engineer about Ohm's law, which defines an ideal resistor.

To understand reality, we must abstract from reality. We model the world in its ideal case and only then do we work backward to incorporate troublesome everyday effects. For example, the transistor is the forerunner of the integrated circuits that make today's information technologies possible. Analysis of early transistor circuits relied on simple abstract models of ideal transistors. Effects were added and the models improved as circuits became more complex and the tasks they were called upon to perform become more demanding. The trained engineer knew which model to use for which situation.[12]

In marketing, such ideal abstractions are now being set forth. For example, two University of Chicago researchers, Blattberg and Jeuland, use a "micro-modeling" approach to examine the "why" of advertising response.[13] Little's postulates specify how the *market* responds to advertising; Blattberg and Jeuland ask whether this market response can be explained as an aggregation of individual consumers responding to advertising. They specify three assumptions:

1. Every consumer has a probability, q, of being exposed to advertising and that probability is the same across consumers.
2. The probability of being exposed to an advertisement is independent from insertion to insertion.
3. Once a consumer sees an advertisement, he or she forgets at a constant rate.[14]

We know that no real-world advertising response will satisfy all of these assumptions; but by studying the implications of these "ideal" assumptions, Blattberg and Jeuland understand the implications of the model and examine how well an ideal advertising response can approximate a real advertising response. Just as Galileo's model of the frictionless plane has been extended to a multitude of practical problems, so will Blattberg and Jeuland's "ideal" microresponse be applied to practical advertising problems. (They themselves suggest how one might deal with the heterogeneity, competitive effects, and varying copy effectiveness.)

With just these three simple assumptions, Blattberg and Jeuland are successful in reproducing observed aggregate effects. For example, their model is consistent with three of Little's five postulates (four if you use the competitive extension) and could readily be modified to handle Little's fifth postulate. More importantly, their model can be used to address Little's question: "Should a 'flight' be half as long and twice as intense?"

A special case of their model (probability of exposure, q, close to zero and equal spacing of advertising insertions) reproduces a model that is similar to the econometric models now in popular use. What's more, the micromodel provides a satisfying explanation of why Clarke found that the "observed" carry-over effect of advertising is heavily dependent upon the observation period (monthly, quarterly, yearly) used to measure the effect.[15] The micromodel demonstrates that this variation is a measurement artifact, not an actual lagged effect.

Thus, we see the progression of marketing theory from observation to more precise measurement to "how" postulates to a "why" theory. Of course, the theory needs testing, elaboration, application, and maybe, a rival theory, but we see in this example the clear interrelationships among empirical research, methodological research, and theory. Contributors, such as Little, Blattberg, Bass, Jeuland, and Clarke, who think deeply about data rather than simply cataloging them, are today laying the foundation for a comprehensive theory of advertising response.

Axioms and the Mathematization of Marketing

> While formal logic and pure mathematics do not in themselves establish any assertions about matters of empirical fact, they provide an efficient and entirely indispensable machinery for deducing, from abstract theoretical assumptions. . . .
>
> Carl G. Hempel
> "Geometry and Empirical Science"

> . . . the great successes of Galileo and Newton consisted in their mathematical analysis of physical events, the combination of them into physical postulates, or "axioms," and the deductive development, from the postulates and definitions of new concepts, of theorems which, since they stated consequences about the physical world, could be tested.
>
> Edward H. Madden
> "Making Sense of Science"

In 1686 Newton modified Galileo's law of inertia (bodies in motion stay in motion, bodies at rest stay at rest unless acted upon by an outside force) and added two mathematical postulates: (1) $F = ma$ for motion and (2) $F = Gm_1 m_2/r^2$ for gravitation where F is force, m is mass, a is acceleration, r is distance, and G is a fitting parameter. With these quantitative laws, or "axioms," and with his mathematical skill, Newton was able to obtain Kepler's "how" laws as just one of many implications of Newton's "why" laws. Newton was also able to explain the tides, falling bodies, and many other observed facts with his three simple axioms. Can we do the same for marketing phenomena? I believe that we can, and we are now trying.

I have already mentioned Blattberg and Jeuland. In their system they too set forth three axioms. They were able to obtain such powerful results because (1) the axioms had very specific quantitative implications and (2) they were able to call upon formal logic and mathematical skill to derive practical and testable implications from their axioms. It is for such applications that managers should examine the writings of the mathematical marketing theorists. For as Hempel points out, ". . . a mathematical theorem, once proved, is established once and for all; it holds with that particular certainty which no subsequent empirical discoveries, however unexpected and extraordinary, can ever affect to the slightest extent."[16]

Thus, if you believe our axioms, then you must believe our results. If the results do not make sense or can be shown to be false, then mathematical logic demands that you question at least one of our axioms. In this way we progress to more sophisticated axioms that better represent the world as we believe it to be.

Let me provide an example from some of my own attempts at theory (in collaboration with Steven Shugan of the University of Chicago). I have written extensively on new product development and the importance of innovation to today's corporations.[17] But in this research it soon became apparent that while managers are interested in developing new products, they also fear competitive new products. For every new product launched, five or six managers must defend their profit from capture by new competitive products. Shugan and I began to study defensive strategy with four ideal axioms that are well supported in the empirical marketing literature.

1. Consumers maximize utility in a multiattributed space.
2. Consumers have heterogeneous tastes.
3. Utility can be approximated by a weighted sum of the product's attributes.

4. The relevant attributes are scaled by price, that is, "effectiveness" per dollar or "gentleness" per dollar.[18]

With these four axioms and an assumption that aggregate advertising response satisfies, at least, Little's second postulate, we were able to show that the following theorems are a necessary logical result. To maintain the best possible profit position, the defending firm should:

A. decrease spending on distribution;
B. decrease spending on awareness advertising;
C. decrease price in unsegmented markets;
D. perhaps, increase price in segmented markets; and,
E. improve the product (and support the improvement with advertising) in the direction of the defender's strength; that is, for the attribute(s) on which the defender's product is better than the attacker's product.

Furthermore, these results are true (if you believe our axioms) no matter what specific details you measure about the advertising response function or no matter what the exact positions are of the attacking and defending products. Of course, how much you decrease distribution spending does depend upon these details.

Steven Gaskin of MIT and I have applied this model to a consumer good category with over $100 million in annual sales. Interestingly, the firm was doing about the best they could before the new product attacked the market. They could have maintained approximately $500,000 more annual profit and three more share points after the attack if they had followed the model's prescriptions. (They decreased advertising and distribution but increased price.)

But I Don't Believe Your Assumptions

> The strangest phenomenon for the philosophical observer, however, was the fact that physical research was not paralyzed by these contradictions, that the physicist managed somehow to go on with two contradictory conceptions and learned to apply sometimes the one, sometimes the other, with an amazing success as far as observational discoveries are concerned.
>
> Hans Reichenbach
> "Are There Atoms?"

> . . . the early developmental stages of most sciences have been characterized by continual competition between a number of distinct

views of nature, each partially derived from, and all roughly compatible with, the dictates of scientific observation and method.

Thomas S. Kuhn
"The Structure of Scientific Revolutions"

Reichenbach refers to the 250-year-old debate among physical scientists about whether light was a particle or a wave. Light has momentum, like a particle, but exhibits interference, and is seen in waves resulting from two pebbles thrown side by side into a pond. (Newton was the founder of the particle theory and his contemporary, Huygens, the founder of the wave theory.) Both theories existed side by side, fading in and out of popularity as new phenomena were discovered; both theories fit some, but not all, of the facts of observation; and both theories led to tremendous technological developments in optics and related engineering application. In fact, it was the dominance of the wave theory of light in the nineteenth century that led scientists to postulate a medium, "luminiferous ether," through which light travels like waves through water. But which theory was right? It remained for twentieth-century quantum theorists to provide an answer.

Let us return now to the defensive marketing theorems. Many managers and some academics find theorem A to be counterintuitive. Surely an aggressive defense must entail strengthening your distribution chain. Since the theorems are a logical result of the axioms, this must mean that at least one axiom is wrong. The favorite target is axiom 4. After all, who ever heard of dividing "gentleness" by price to get "gentleness per dollar"? It is common knowledge (pick up any textbook on market research) that gentleness is at most an "interval" scale, not the required "ratio scale."

Actually, with all mathematical theories, each theorem does not require all the axioms and theorem A does not depend upon axiom 4. It depends only on Little's second postulate applied to distribution response. To better understand theorem A, recognize that the defending manager faces a smaller demand for his product than he did before the attack. It is no longer in his interest to invest in the marginal distributor. What the theorems really say is that price and repositioning are better weapons for defense than distribution and awareness advertising.

Theorem A does not depend upon axiom 4, but the pricing theorems, C and D, do. Should we reject them because common belief holds that "gentleness per dollar" is an unmeasurable construct? Many have said we should. But economic theory and deductive reasoning from the postulate that consumers maximize utility subject to a budget constraint suggest that consumers should use "gentleness per dollar," not "gentleness," to evaluate a product such as Tylenol.[19] Rather than throw out this strange notion, Gaskin and I set up an experiment in which we used two alternative models—(1) attributes scaled by price and (2) price as another attribute—to forecast the share of a new product.[20] Model 1, based on axiom 4, predicted a market share of 7 percent. Model 2, with price as an attribute, predicted a share of 18 percent. The actual share observed one year later was 7 to 8 percent. Success! Or is it?

Good arguments can be made in favor of model 2.[21] And such models have also predicted well.[22] Because our model 2 was only one of many potential ways to model price as an attribute, we have not shown the dominance of model 1, but rather the feasibility of model 1.[23] We can say from our empirical experiments to date that the four defensive axioms make some empirical sense and that they should not be rejected simply because the results suggest departure from intuition. Perhaps, price should be modeled sometimes as an attribute and sometimes as a scaling factor, just as light, for 250 years, was modeled sometimes as a wave and sometimes as a particle.

Such a duality theory was extremely powerful for the advancement of optics. It was only in 1924, when Louis de Broglie set forth a theory that light *and matter* have the properties of *both* waves and particles, that the two contradictory theories could be reconciled. De Broglie's theory was subsequently demonstrated empirically and led to revolutionary ideas in quantum mechanics. Axioms are important, but they cannot be taken entirely on faith. Successful axioms are (eventually) tested and empirically grounded in an iterative process of theoretical and empirical research.

Researchers in consumer behavior argue strongly that experiments that attempt to falsify theory are important in guiding theory.[24] But falsification is a complex philosophical point. "Ideal" models are difficult to falsify. How can you falsify "bodies in motion stay in motion unless acted upon by an outside force"? Not only is it physically impossible to rule out all forces—for example, the gravitational pull of the sun—but if anything stops the object, it is, by definition, a force. Nonetheless, the (definitional) law of Galileo and Newton led to a scientific and technological revolution.

Even theories that are eventually rejected are valuable in helping us understand empirical phenomena. Consider Lorentz contraction. The chief spokesman of the falsification philosophy of science, Karl Popper, has cited Lorentz contraction "as an auxiliary hypothesis which should be excluded from empirical science by the falsifiability criterion."[25] But it was Einstein providing, in part, a "microtheory" to explain Lorentz contraction who developed the special theory that led to the twentieth-century revolution in physics.[26] Thomas Kuhn cautions us: "No process yet discovered by the historical study of scientific development at all resembles the methodological stereotype of falsification by direct comparison to nature."[27]

I believe in a middle ground between the falsificationists and Kuhn. I believe that while falsification experiments can be important, they alone are not sufficient to the advancement of theory. They are part of a greater whole that includes exploratory data collection, theory formulation, deductive reasoning, and practice. I am uncomfortable with any claim that one component in the pursuit of knowledge is uniquely qualified to be called science.

We must be critical. We must question our axioms. But we must also proceed with caution. The implications of axioms, even axioms we question, help guide theory and, inevitably, lead to improved theory and more powerful and useful implications.

But Is Your Model Relevant?

> Both in mathematics and astronomy, research reports had ceased already in antiquity to be intelligible to a generally educated audience. In dynamics, research became similarly esoteric in the Middle Ages. . . . Too little attention is paid to the essential relationship between that gulf and the mechanisms intrinsic to scientific advance.
>
> Thomas S. Kuhn
> "The Structure of Scientific Revolutions"

> Newton had, in the theory of universal gravitation, created what would today be called a mathematical model of the solar system. And having once made the model, he followed out a host of its other implications.
>
> A. P. French
> *Physics: A New Introductory Course*

It is the vogue to attack mathematical theory as being of no relevance to managers. Such attacks are unfortunate, because mathematical theory is relevant. For example, Little has demonstrated time and again that his models help real managers make real decisions and that such decisions lead to better outcomes than would have been obtained without the mathematical analysis.[28]

My MIT colleagues, Alvin Silk and Glen Urban, have developed

a forecasting model, based on mathematical marketing theory, that has become a viable commercial enterprise.[29] In over three hundred applications, the model has performed well, providing extremely accurate predictions of a new product's market share, predictions that are made *prior* to test marketing. Recently, Glen Urban looked back at the three hundred applications and used scientific methods to evaluate the model in terms of its utility to managers.[30] According to Urban's estimates, the value of the model in incremental profit per new product launched could be as much as $11 million. That's relevance. Even if these estimates are inflated by a factor of ten, such an impact suggests that the Silk-Urban model cannot be ignored.

If such models are so valuable, why, then, are they attacked by otherwise brilliant managers? I believe the attacks come because managers do not speak "pure mathematics." If I write "Šitas sakinys yra aiškus tam, kuris skaito lietuviškai," I would expect few of you to understand me. But if you spoke Lithuanian, one of the world's oldest living languages, you would find the sentence perfectly clear. Further, if you do not speak Lithuanian, you would be willing to await translation before judging the relevance of the statement. On the other hand, if I write $\nabla \times \vec{B} = (1/c)(\partial\vec{E}/\partial t) + (4\pi\rho/c)\vec{J}$, I am inundated with questions about relevance to managers. I am not even allowed a translation. I am guilty until proven innocent. But an equation is a sentence; mathematical operators such as $\nabla\times$ and $\partial/\partial t$ are verbs, and symbols such as $\vec{E}$, $\vec{B}$, and $\vec{J}$ are nouns. Once you know the language, the above equation becomes one of the fundamental equations of electromagnetism. It is of enormous relevance for the design of the information technologies that are the theme of this conference. But you must speak the language to use the equation itself.

There is no reason to expect managers to speak "pure mathematics" any more than Lithuanian. They can survive without either. For Lithuanian they can hire a translator; for electronics they can hire an engineer or simply use the technology created by the engineers. But an engineer is a doer for electronics just as a manager is a doer for marketing.

It is, in part, incumbent upon mathematical marketing theorists to translate their work. This will happen as they apply their work. But I also see more and more mathematically trained engineers being attracted to marketing management. Such engineers will be the first to use mathematical theory and manage better. With their success this theory will become attractive to all managers, as has today's computing and information technology.

But Your Theory Is Not Complete

> To be accepted as a paradigm, a theory must seem better than its competitors, but it need not, and in fact never does, explain all the facts with which it can be confronted.
>
> Thomas S. Kuhn
> "The Structure of Scientific Revolutions"

> He presented mathematicians with the astounding and melancholy conclusions that the axiomatic method has certain inherent limitations, which rule out the possibility that even the ordinary arithmetic of the integers (whole numbers) can ever be fully axiomized.
>
> E. Nagel and J. Newman
> *Gödel's Proof*

Newton's laws were not complete; some might say that they were wrong. But this does not diminish in any way the impact that they had on the technological and social revolutions they served to foster. Nor does Einstein's theory diminish Newton's genius. Without Newtonian mechanics there would have been no Einsteinian mechanics. As Einstein himself pointed out, "The old mechanics is valid for small velocities and forms the limiting case of the new one."[31] By small velocities, Einstein means that Newtonian mechanics will be within a percentage point for any velocity less than 94 million miles per hour. That covers a lot of practical cases and Newton's theory is much easier to apply.

It is not clear that even Einstein's theory is or ever can be complete. Not only did Einstein fail to achieve a complete unification of force fields, but developments in mathematical logic suggest that no set of axioms can ever be complete because there will always be propositions that can neither be proven nor disproven with the axiom.[32] This statement (for arithmetic) is the mathematical proof published in 1931 by Kurt Gödel to which Nagel and Newman refer. Gödel's proof is exceedingly complex, but its implication is that it is logically inconsistent to expect even the axioms of simple arithmetic to be complete, let alone a set of axioms that refer to empirical marketing phenomena.

Despite the warnings from the history of science and from pure logic, we all too often criticize mathematical marketing theories as incomplete. Such criticisms are valid to the extent that they caution us from blindly applying a theory beyond the boundaries of its axioms. But such criticisms are counterproductive if they prevent us from using our theories for the problems they can solve productively. It is the investigation and extension of axiomatic boundaries that makes marketing a science. For example, in proving the defensive marketing theorems, Shugan and I assume that the main actors are (1) the attacking firm and (2) the defending firm. We assume that the net result of all movements by other firms will not reverse the basic results. It is easy to advance intuitive arguments to suggest that this is true, but we have not yet proven this result from axioms. It is a challenge to which we will rise, but such proofs require time.

In the meantime, our theories are clearly valid for gaining insight into defensive problems. (When Newton demonstrated his law of universal gravitation, he knowingly ignored second-order forces such as the effect of Mars on the orbit of the moon. It remained for later researchers to complete such second-order analyses.) Let me illustrate, with the Farley-Srinivasan sales force compensation problem, the time scale and style of research necessary to elaborate axioms. In 1964, John Farley of Columbia University published a seminal article on sales force compensation.[33] In that article he showed that for a firm to maximize profit, it should pay salesmen an equal percentage of gross margin across all products. To derive his result, Farley assumed that the salesman's total time was fixed a priori, an assumption that Srinivasan would later question. With this assumption, for the next seventeen years Farley's insights led to elaborations of theory, empirical tests, applications, and most importantly, valuable insights into the problem.

In 1981, V. Srinivasan of Stanford University asked, "Does this result hold if we must also motivate the salesman to allocate his (or her) time to selling?"[34] This question had been asked by others. Srinivasan's contribution is that he was able to use his mathematical skill to provide an answer. The answer is yes, but only in two restricted cases, one of which is Farley's fixed time axiom. Thus, as Einstein asked a fundamental question, "Is the velocity of light constant for all reference frames?" and used his mathematical skill to generalize Newton's theory, so Srinivasan has asked a fundamental question and used his mathematical skill to generalize Farley's theory. There are other results in Srinivasan's theory, including a case where it is optimal to pay salesmen a fixed percentage of gross sales, but I need not elaborate them here.

Srinivasan's contribution is not simply that he generalized Farley's theory. He helped us to better understand the problem. He showed us the boundaries of the theory and directed us to the critical assumptions necessary to apply the theory in real applications. Managers must now decide which assumptions best approximate their situations. They can then apply the appropriate compensation scheme.

Is Srinivasan's theory complete? Of course not. Srinivasan himself suggests valuable new avenues of research and active research is being undertaken along these lines in at least three universities. For example, issues of uncertainty add a new perspective on the problem and lead to new insights, insights that add to, rather than detract from, previous results.

Theory advances with challenge, extension, modification, and sometimes, revolution. But it rarely springs forth without roots in other theories and in precise measurement of marketing phenomena.

Who Is the Horse and Who Is the Driver?

> Only very occasionally, as in the cases of ancient statics, dynamics, and geometrical optics, do facts collected with little guidance from preestablished theory speak with sufficient clarity to permit the emergence of a first paradigm.
>
> Thomas S. Kuhn
> "The Structure of Scientific Revolutions"

> [Einstein] seemed to know the answers without the benefit of anything more than a hint or two from nature; the rest was mere confirmation.
>
> A. P. French
> *Relativity: An Introduction to the Special Theory*

I have argued that information technology will lead to the greater precision necessary for a revolution in marketing theory. But how will that revolution come about? Should we thrash around in the data until we are shocked by the facts, or is there a better way? We have seen the role that the data of Tycho Brahe played in the revolution of celestial mechanics. But Tycho Brahe's data were not collected at random; they were collected with the purpose of unifying the Ptolemaic and Copernican theories.

Consider the famous Michelson-Morley experiment. The wave theory of light suggested that there exists a luminiferous ether through which light travels like waves through water. If there were a luminiferous ether and if the earth were traveling through this ether, then we should be able to detect an "ether wind" as we detect a wind when we thrust our hand outside the window of a moving car. An ether wind should manifest itself through a drag on the velocity of light. Unfortunately, the leading figure in electromagnetic phenomena, James Clerk Maxwell, demonstrated convincingly that the effect of the drag was too small to measure. It would be one part in 100 million. But in 1881 Michelson invented a new instrument of such accuracy that an ether wind would be detectable. Much to his dismay, he found no ether wind. Even with an instrument ten times as accurate, he and Morley could still find no effect.

The Michelson-Morley experiment led the Dutch theorist, Lorentz, to postulate a contraction of all objects due to motion, and an independent derivation of this contraction was a key component in Einstein's theory. Although Einstein claimed not to have had any direct knowledge of the experiment itself, the experiment obviously influenced contemporary physics theory, which in turn influenced Einstein.

But the Michelson-Morley experiment would not have been performed and would need no interpretation without the theory of luminiferous ether. *It was a null result.* It said only that light travels at the same velocity in all directions. It would have been of little relevance without theory.

Such anecdotes from the history of science suggest that perhaps we should not simply use information technology to collect data blindly and then try to interpret them, but rather, we should perhaps use mathematical theory to guide our investigations.

For example, in application of the defensive axioms we assume that they hold for all products that a consumer evokes and that evoking can best be modeled with a response function satisfying (at least) Little's second postulate.[35] Derivations based on the axioms suggest that a price-off promotion will have two effects: One effect will result because a promotion increases evoking, and will appear as a promotion response more or less independent of price. The second effect will manifest itself as would any change in price. Curiously, these are exactly the effects that Guadagni and Little found in their sophisticated analysis, using information technology, of in-store promotions.[36]

Thus, precision, measurement, experimentation, and observation are crucial for the advancement of theory. But the circle is complete. Theory is crucial for deciding which marketing phenomena to measure. For example, the most significant effect that Little and Guadagni identified with their data was an unexplained "loyalty" factor, that is, the tendency of consumers to continue to purchase products they already purchased in spite of price changes and promotion. Such an effect is predicted by the first defensive marketing axiom that each brand has its unique position in a multiattributed space. Predictions with respect to this phenomenon are specific and could be tested. Such research would be interesting and valuable to the advancement of theory, but information on positioning is not currently collected in electronic shopping panels.

How Should We Proceed?

> Roughly speaking, we may distinguish, according to Max Planck, two conflicting conceptions in the philosophy of science: the metaphysical and the positivistic conception. Each of these regards Einstein as its chief advocate and most distinguished witness. If there were a legal case to be decided, it would be possible to produce satisfactory evidence on behalf of either position by quoting Einstein.
>
> Philipp Frank
> *Einstein, Mach, and Logical Positivism*

> You, who are blessed with shade as well as light, you, who are gifted with two eyes, endowed with a knowledge of perspective, and charmed with the enjoyment of various colours, you, who can actually see an angle, and contemplate the complete circumference of a Circle in the happy region of the Three Dimensions—how shall I make clear to you the extreme difficulty which we in Flatland experience in recognizing one another's configuration?
>
> Edwin A. Abbott
> *Flatland*

It has become popular in marketing journals to argue how one should proceed with the science of marketing. I do not wish to enter that debate. My thesis is not that we should proceed with mathematical marketing theory, only that such theory is inevitable. It will result from increased precision, new information, and probing minds. There will be a revolution in marketing theory. The foundations are now being built. I have focused on mathematical theory, but marketing theory cannot stand alone in the absence of an empirical base. It is intimately related to a myriad of other scientific pursuits.

There is a role for everyone. We have seen that data collection (Tycho Brahe); experimentation (Michelson-Morley), and observation (Ptolemy, Copernicus, Galileo, Newton, Einstein), are critical components in the discovery of scientific knowledge. Such work is now proceeding in marketing science. I have not discussed engineering, but it is clear that those who use theory to solve real problems must themselves develop and modify theory to make it practical.

But what about doers, those managers who must every day solve complex marketing problems? If we only remember that it was the need to develop a practical calendar that was, in part, behind the Copernican revolution, we see that the doer, the person who demands, needs, and uses practical solutions, is at the core of theoretical development whether he knows it or not.

We are all in this together as we each pursue our own interests. Each learns from the other, and each in his or her own way is a necessary part of the coming revolution in marketing theory. Throughout this essay, I have provided examples of marketing theory. These examples are only a sample of the valuable work now being published.[37]

pected rate of return on a well-diversified investment portfolio (e.g., *Standard and Poor's* 500) and DE and r_f are as defined before.

23. Coate, "An Empirical Analysis of the BCG Portfolio Model."

CHAPTER 20

1. R. C. Blattberg and K. J. Wisniewski, "Sales Response Estimation Using UPC Scanning Data," paper read at the First Marketing Science Conference, University of Southern California, Los Angeles, March 16–18, 1983.
2. P. M. Guadagni and J. D. C. Little, "A Logit Model of Brand Choice Calibrated on Scanner Data," *Marketing Science*, vol. 2, no. 4, Summer 1983.
3. A. Kuritsky, J. D. C. Little, A. J. Silk, and E. S. Bassman, "The Development, Testing, and Execution of a New Marketing Strategy at AT&T Long Lines," *Interfaces* 12 (December 1982): 22–27.
4. *Encyclopedia Americana* (1967), vol. 4, p. 393. All dates and descriptions of the Copernican revolution are from the *Encyclopedia Americana*.
5. A. P. French, "Particles and Newtonian Mechanics," in *Physics: A New Introductory Course* (Cambridge, Mass.: M.I.T. Science Teaching Center, 1965), pt. 1, pp. 11-17, 11-18.
6. For example, see J. D. C. Little, "A Model of Adaptive Control of Promotional Spending," *Operations Research* 14 (November-December 1966): 1075–98. Interestingly, Little's doctorate is in physics and he is also well known for his work in queuing theory and traffic signal optimization.
7. J. D. C. Little, "Aggregate Advertising Models: The State of the Art," *Operations Research* 27 (July-August 1979): 629.
8. Ibid., p. 644.
9. Ibid.
10. F. M. Bass, "A Discussion of Different Philosophies in the Analysis of Advertising-Sales Relationships," and J. D. C. Little, "Comments on Bass." Papers read at the First Marketing Science Conference, The Institute of Management Sciences, University of Southern California, Los Angeles, March 16–18, 1983.
11. E. H. Madden, "Making Sense of Science," in E. H. Madden, ed., *The Structure of Scientific Thought* (Boston, Mass.: Houghton-Mifflin, 1960).
12. See P. E. Gray and C. L. Searle, *Electronic Principles: Physics, Models, and Circuits* (New York: John Wiley, 1969).
13. R. C. Blattberg and A. P. Jeuland, "A Micro-modeling Approach to Investigate the Advertising-Sales Relationships," *Management Science*, September 1981, pp. 988–1005.
14. Ibid., p. 989.
15. Clarke demonstrated this phenomenon in an insightful review of the econometric literature on advertising lag effects. See D. G. Clarke, "Econometric Measurement of the Duration of Advertising Effects on Sales," *Journal of Marketing Research* 13 (1976): 354–357.
16. C. G. Hempel, "Geometry and Empirical Science," *American Mathematical Monthly* 52 (1945), pp. 7–17. Reprinted in Madden, *The Structure*, pp. 71–80; quote is from p. 71.
17. See, for example, G. L. Urban and J. R. Hauser, *Design and Marketing of New Products* (Englewood Cliffs, N.J.: Prentice-Hall, 1980).
18. J. R. Hauser and S. M. Shugan, "Defensive Marketing Strategy," *Marketing Science*, vol. 2, no. 4, Fall 1983, pp. 319–360. See also the detailed discussion and empirical justification of the axioms.
19. For example, K. Lancaster, *Consumer Demand: A New Approach* (New York: Columbia University Press, 1971). But such ideas are classical as well. See marketing interpretation in J. R. Hauser and P. Simmie, "Profit Maximizing Perceptual Positions: An Integrated Theory for the Selection of Product Features and Price," *Management Science*, vol. 27, no. 1, January 1981, pp. 33–56.
20. J. R. Hauser and S. P. Gaskin, "Application of the 'Defender' Consumer Model," *Marketing Science*, vol. 3, no. 4, Fall 1984.
21. See, for example, V. Srinivasan, "Comments on the Role of Price in Individual Utility Judgments," in L. McAlister, ed., *Choice Models for Buyer Behavior* (Greenwich, Conn.: JAI Press, 1982).
22. See, for example, predictive tests in A. M. Tybout and J. R. Hauser, "A Marketing Audit Using a Conceptual Model of Consumer Behavior: Application and Evaluation," *Journal of Marketing* 45 (Summer 1981): 82–101; and J. R. Hauser and G. L. Urban, "A Normative Methodology for Modeling Consumer Response to Innovation," *Operations Research* 25 (July-August 1977): 579–619.
23. There are other confounding factors to consider in our experiment. For example, model 1 is based on axiom 4, but it also relies on axiom 2, heterogeneity of consumer tastes. Our model with price as an attribute did not use the full power of axiom 2. Thus, one can also interpret our experiment as favoring heterogeneity of consumer tastes over heterogeneity of consumer perceptions. A later test using a model combining axiom 2 and price as an attribute showed that the effect is still there but somewhat mitigated. See Hauser and Gaskin, "Application of the 'Defender' Consumer Model."
24. See, for example, B. J. Calder, L. W. Phillips, and A. M. Tybout, "Designing Research for Application," *Journal of Consumer Research* 8 (September 1981): 197–207. For example, they state on p. 198: "Theory applications call for falsification test procedures" and "Theories that survive rigorous attempts at falsification are accepted and accorded scientific status."
25. J. Losse, *A Historical Introduction to the Philosophy of Science* (New York: Oxford University Press, 1972), p. 192.
26. Einstein's derivation, however, was independent of Lorentz's derivation. Such contraction is still known as Lorentz contraction, or, occasionally, Lorentz-Einstein contraction. See A. P. French, *Physics*, pt. 2, chap. 3. One can argue that Einstein would have discovered this con-

traction anyway without Lorentz, but who can really say that Lorentz's work did not indirectly influence Einstein or that Lorentz's work did not facilitate the acceptance of Einstein's radical theories. (Lorentz contraction is the phenomenon that objects in motion with a velocity, v, relative to the frame of reference appear to be shorter by a factor of $(1-v^2/c^2)^{1/2}$ where c is the velocity of light.)

27. T. S. Kuhn, "The Structure of Scientific Revolutions." Reprinted in *Foundations of the Unity of Science: Toward an International Encyclopedia of United Science*, vol. 2, no. 2 (Chicago: University of Chicago Press, 1970), p. 139.
28. J. D. C. Little, "Decision Support Systems for Marketing Managers," *Journal of Marketing* 43 (1979): 9–27.
29. A. J. Silk and G. L. Urban "Pretest Market Evaluation of New Packaged Goods: A Model and Measurement Methodology," *Journal of Marketing Research* 15 (1978): 171–91.
30. G. L. Urban and G. M. Katz, "How Accurate Are Simulated Test Markets and How Should Managers Use Them?" in R. K. Srivastava and A. D. Schocker, eds., *Analytic Approaches to Products and Marketing Planning: The Second Conference* (Cambridge, Mass.: Marketing Science Institute, 1982).
31. A. Einstein and L. Infeld, "The Evolution of Physics" (1938), in French, *Physics*, pt. 2, chap. 1, p. 1.
32. For example, you can neither prove nor disprove the existence of an infinity larger than the number of integers (countably infinite), yet smaller than the number of points on a real line between 0.0 and 1.0 (uncountably infinite). For nonmathematical readers, there are as many points in the one-dimensional interval between 0.0 and 1.0 as there are in a three-dimensional universe that stretches to infinity in all directions. At infinity we must rely on deductive logic, not intuition.
33. J. U. Farley, "An Optimal Plan for Salesmen's Compensation," *Journal of Marketing Research* 1 (1964): 39–43.
34. V. Srinivasan, "The Equal Commission Rate Policy for a Multi-Product Salesforce," *Management Science*, July 1981, pp. 731–56.
35. By *evoking* we mean that the consumer has enough information about the product so that he or she can evaluate it. This is a stronger condition than awareness of the product.
36. See note 2.
37. The thoughts expressed in this essay are the result of many stimulating discussions I have had with my colleagues. Those who have influenced my personal philosophy include John Little, Glen Urban, Al Silk, and Leigh McAlister of M.I.T.; Steve Shugan and Abel Jeuland of the University of Chicago; Brian Sternthal and Alice Tybout of Northwestern University; Lynn Phillips and Seenu Srinivasan of Stanford University; Ted Levitt of Harvard University; Rheinhard Angelmar of INSEAD: Claes Fornell of the University of Michigan; Frank Bass of the University of Texas at Dallas; and Jehoshua Eliashberg of the University of Pennsylvania. My thanks in particular to my friend and fellow M.I.T. EE graduate, Dr. Edward McHale of the Foxboro Company, *mano geras draugas*.

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CHAPTER 21

1. Published by Transaction Books, New Brunswick, New Jersey, 1981.
2. In the specific case of Bass, we should note that his quest has been marked mostly by a desire to help guide actions rather than to discover laws.
3. Stephen E. Toulmin, *Foresight and Understanding: An Inquiry into the Aims of Science* (Westport, Conn.: Greenwood Press, 1982). Originally published by Harper & Row, New York, 1963.
4. Thomas V. Bonoma, "A Case Study in Case Research: Marketing Implementation," Harvard Business School, May 1983 (mimeograph).

2