THE ONSLAUGHT OF COMPLEXITY

Information Technologies and Developments in Legal and Economic Thought

by
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To the importance of History:

My Family

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"...a recent theory called the Gaia hypothesis asserts that climate, and even the chemical makeup of the atmosphere, is highly co-evolved with all the Earth's organisms, including us.

Including us. That's the kicker, because the co-evolutionary idea of life more intricately fitting, fighting, cooperating with, and learning from other life only picks up speed and complexity when you mix in cultural species such as we.

The moral of the co-evolutionary perspective is its imperative to always look one level larger and one level finer (at least) than where you are, and to see clear through your cycles. So as you study your soil, your yard, your watershed, your bio-community and human community, your weather, your access to tools, and your night sky, be aware that they are studying you."

Statement of purpose:

The Co-Evolution Quarterly

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Chapter I

THE MODEL OF INCREASING COMPLEXITY

1. The Importance of History. The noted economist Wesley C. Mitchell said in 1927:

> A study of the classics [in his discipline] enables a scientific worker to understand the limitations of his knowledge, the fallibility of his insights, the variety of his talents, the degree to which he is the child of his age, and the dangers of overspecialization.(1)

Too often we learn the techniques of our discipline from textbooks which leave out history almost entirely in their efforts to present the currently accepted dogmas more efficiently.

This thesis will examine the history of what has been among the most ahistorical of disciplines, a discipline which will be called "information technologies." The term "information technologies," defined below with greater exactness,(2) basically refers to certain approaches to problems which have evolved in the United States during the past one hundred years. The new science of statistics expanded rapidly after about 1900, and systems thinking related to the computer began during and after World War II.

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(1) Quoted in Joseph Dorfman The Economic Mind in American Civilization Vol III, p. 373.

(2) Infra, Chap. I, sec. 4.

Such information technologies proved very effective at describing and predicting the increasingly complex nature of modern society.

As a result of their effectiveness, information technologies spread into other fields. For example, the histories of economic and legal thought parallel the history of information technologies in remarkable detail. This thesis will describe the histories of these three fields-- information technologies, economics, and law-- as they progressed from the period before the use of statistics, to the period of statistics, and then to the period of systems thinking.

2. A Children's Story. One early sign of brightness in some children is a fascination with very large numbers-- billions, trillions, and so on up to zillions. As the child grows, he(3) wants to do more than merely name the numbers; the young lover of mathematics learns to manipulate them, principally through study of arithmetic. As he passes through adolescence, a third stage occurs. The child learns whole systems of thought-- first algebra and geometry, but eventually matrix algebra, and so on as far as he can or will go.

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(3) Following conventional usage, I will use "he" generically to denote both male and female. No sexism is intended.

Despite their huge size, the large numbers of the first stage actually involve quite simple concepts. All the numbers lie in a row-- like "beads on a string"(4) --and one simply counts bead by bead until reaching a sufficiently big and impressive-sounding stopping point.

The second stage brings a few complications. To solve the new problems, the child names concepts such as fractions and irrational numbers. He learns about special relations among concepts, such as conversions between fractions, decimals, and percentages, and also about the need in some cases to round off an answer.

The typical grade school student accepts his arithmetic from the teacher-- add this here and subtract there to get the answer. Examples from everyday experience are easily found: slices of a pie for fractions, or two oranges for Jane and three oranges for Anne-Marie makes five oranges for them together.

Once in high school, our student learns to generalize. In algebra he finds Jane's "x" oranges added to Anne-Marie's "y" oranges. The student solves complex word problems, and winnows all the initial information down to the desired answer. By grasping the nature of a proof, the student makes a crucial breakthrough; he can go beyond the

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(4) See Nicholas Georgescu Roegen, The Entropy Law and the Economic Process 1971, Appendix A, "On the Texture of the Arithmetic Continuum," pp. 367-387.

recitations of his teacher, and begin the process of independent discovery.

3. A Grownup Story--The Model of Increasing Complexity. Such a three-stage model of growth does not happen only to young mathematicians. While always recognizing the dangers of abstracting too far from historical detail, this thesis will suggest that the story describes quite well the growing complexity of American life during the past century. In a three-stage "model of increasing complexity," the counting of large numbers will be called the "deductive" stage; the arithmetic of fractions and irrational numbers will be called the "inductive" stage; and the algebra-- the abstract equations which operate on real numbers-- will be called the "inductive modelling" stage.

The linked ideas of form, substance, and function characterize each stage in the model. Form refers to the way people perceive the shape of the objects of study; the increasing complexity of the number line will serve as a metaphor for those perceptions. Substance refers to the techniques by which people manipulate the objects of study; the number of variables and the nature of causation included in the analysis indicate people's perceptions of the substance they are studying. Finally, function refers to the goals of the analysis--whether to explain the past, describe the present, or predict the future. Appendix I has a table summarizing the form, substance, and function of each stage.

The form of the deductive stage is that of a string-of-beads number line, like the one the child used to count to a zillion. A person can observe each bead as discrete from any other bead. The substance of the deductive stage consists of only two variables, tied together by deterministic causation. Any change in the one independent variable determines a precisely measurable change in the other, dependent variable. After such a change, the process can repeat exactly, beginning with another change in the independent variable. The function of the deductive stage is to trace the universal laws which underlie the movements of the two variables. We can call such analysis "past-oriented" in the sense that the analyst seeks for deterministic relations between variables as they have always existed in the past.

Introductory economics offers an excellent example of such a deductive model: For a demand function, a change in the independent variable (price) determines a change in the dependent variable (quantity). The actions of the rational, autonomous individual in the marketplace mediate the change. The change is discrete both in number and time; quantity changes by some exact amount during some precise amount of time. The goal of the analysis is to discover the unchanging relation between the two variables.

The inductive stage substitutes a large dose of empirical data for the abstractions of the deductive stage. Instead

of analyzing the discrete objects of the string-of-beads number line, it accepts the fact that observational errors always occur, and suggests the new form of a continuous number line with margin left for such errors. The need for such margins suggests that rather than analyzing discrete individuals, inductivists should study the distribution of a population around a mean. Analysts in the inductive stage lose faith in the strict separation between independent and dependent variables and depend for their substance on the statistical causation typical of correlation analysis. Their function becomes more present-oriented; they reject the elegant structures of universal laws for a more accurate description of the present-day world as measured by empirical data.

In this stage, analysts have great difficulties organizing all the observations into coherent explanations.(5) The overabundance of data swamps their attempts at analysis, and they must find tricks for simplifying problems. As a result, they tend to fall back on the familiar deductive models of the first stage, and simply use the new data to correct those models for observable inconsistencies. To give an analogy, in balancing a checkbook, worrying about every last penny can require long calculations which can often include nagging mistakes. Rounding to the nearest

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(5) See Carl G. Hempel, Philosophy of Natural Science 1966, Chap. 5, for an account of the difficulty of statistical "explanation."

dollar (a discrete bead) would greatly speed computations. If greater accuracy is needed, merely correct afterwards for rounding mistakes.

The inductive modelling stage has the form of a system: "an integrated assembly of interacting elements designed to carry out cooperatively a predetermined function."(6) The substance includes many variables which interact over time. Causal connections often become counterintuitive, as the many variables affect each other in complex ways. The function becomes future-oriented, as the analyst tries to organize all possible data so as to achieve the predetermined goal.

Many inductive models use the computer to solve a large matrix of equations. Unlike the rigid models of the deductive stage, such matrices are flexible, since the programmer can always modify the form of the equations. At the same time, the matrices avoid the limitations of the inductive stage, since those equations, combined with quantitative empirical observations, provide great predictive power. In order to match the form imposed by these matrices, inductive modellers must operationalize all variables, which means that "every scientific term must be specifiable by indicating a definite testing operation [for the computer, a

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(6) Ralph E. Gibson, "The Recognition of Systems Engineering," p. 58, in Charles D. Flagle, William H. Huggins, and Robert H. Roy, Operations Research and Systems Engineering. 1960.

quantitative measurement] that provides a criterion for application."(7) For example, in the case of a factory polluting a lake, operationalization would require the reduction of all the many qualities of a clean lake to numerical scales of costs against which to balance the economic benefits of the factory.(8)

The inductive modelling approach requires the discarding of the second-stage form of a population distributed around a "true" mean on a continuous number line.(9) Two reasons prevent the possiblity of finding such a "true" mean: (a) operationalization, while essential to any solution by computer, always carries with it the inaccuracy of ignoring any unquantifiable qualities of a variable; and (b) in a dynamic system, all variables change over time, eliminating the relevance of the concept. In place of a number line, the third stage expands into an interactive network.

4. Information Technologies. Crucial to the unfolding of the model of increasing complexity is the development of practical techniques for solving each stage's characteristic

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(7) Hempel, p. 88.

(8) Ordinal rankings can also sometimes suffice. See the discussion of quality, cardinality, and ordinality in Georgescu-Roegen pp. 97-105.

(9) See, e.g., the discussion of the contrast between "sample" and "population" values in Thomas and Ronald Wonnacott, Introductory Statistics for Business and Economics 2nd ed., 1977, p. 77-79. In second-stage statistics, one does eventually approach the "true" population mean, sigma, given enough observations.

problems. For example: problems of deduction require rules of formal logic; problems of induction require mathematical techniques for assessing the significance of a set of observations; and problems of inductive modelling require mathematical techniques for solving large sets of interactive equations. In this paper, the description of such techniques will center on the term "information technologies."

The term "information technologies" requires clarification. Following Daniel Bell, technology is "the use of scientific knowledge to specify ways of doing things in a reproducible manner."(10) "Technology" in this paper refers to a particular approach to problems. In general it is broader in meaning than a "technique"-- "a technical method of accomplishing a desired aim,"(11) though the two terms often blur together.

Several types of technologies exist. Bell says: "The reorganization of a hospital or an international trade system is a social technology, as the automobile or a numerically controlled tool is a machine technology."(12) He goes on to discuss "intellectual technologies" defined by "the

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(10) Bell, p.29. Quoted from a speech by Harvey Brooks. Emphasis in the original.

(11) Webster's Third New International Dictionary 1967, p. 2348. The different meaning of "technique" in Jacque Ellul's Technological Society derives from difficulties in translating "la technique" from French.

(12) Bell, p.29. Emphasis in the original.

substitution of algorithms (problem-solving rules) for intuitive judgments."(13)

Bell's intellectual technologies closely resemble the world-view discussed above for the inductive modelling stage. Bell includes in his description such concepts of inductive modelling as: the preoccupation with quantitative data; the role of the computer; and the interactive nature of a system.(14) However, intellectual technologies fall short of the intended meaning of information technologies in two important respects.

First, intellectual technologies include only the products of the third stage of this paper's model. Yet the inductive models of that stage depend heavily on important advances in mathematics and statistics during the inductive stage. The importance of algorithms to thought patterns, as will be shown below, predates the computer,(15) so the broader term, information technologies, is preferable. Second, the two words have substantially different meanings, and information better describes the subject matter. Intellectual is a general term referring to many sorts of mental activity. As such, it has no special link with second- and third-stage thinking.

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(13) Ibid. p. 29.

(14) Ibid. pp. 29-32.

(15) Infra, Chap II., sec. 2.

Information, on the other hand, has a definition well-matched to the latter stages of the model. Information does not exist unless it is communicated.(16) A second meaning of the word comes from information theory, and it refers to the characterization of "the statistical nature of the whole ensemble of messages which a given kind of source can and will produce."(17) In this second meaning, the measure of information does not concern itself with the content of the message, but only with how accurately a given message is conveyed. Given these two definitions, the term information accurately describes the trends towards perception of process within a system; the importance of measurement; and the uncertainties surrounding that measurement.

5. One-Page Synopsis of American History. The latter half of the nineteenth century exhibited many traits of first-stage thought. Information technologies did not yet have much form. In economics, the deductive models of the classical, laissez-faire school dominated completely. The law, in keeping with the model of the autonomous individual, set strict limitations on the liability of one person for damage done to another.

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(16) See Fritz Machlup, The Production and Distribution of Knowledge in the United States 1962, p.9, 14.

(17) Warren Weaver, "Recent Contributions to The Mathematical Theory of Communications," in Claude Shannon and Warren Weaver, The Mathematical Theory of Communication, 1949, p. 105.

Around the turn of the century, America entered the inductive stage. Statistics began as a separate field of study sometime after 1890. The institutionalist economists such as Thorsten Veblen and Wesley Mitchell challenged the classicists with a call for empiricism. Law began the phase of sociological jurisprudence-- a looking outward for new data to help in the resololution of cases.

Stage three started during and after World War II. The development of the computer vastly aided the development of operations research, cybernetics, and other variants of systems analysis. Econometrics fluorished, and both public and private managers learned the intricacies of input-output analysis. In law came the flowering of what Owen Fiss calls the "structural suit" as a partial replacement for earlier suits more concerned with resolving disputes among individuals.(18)

6. Goals of the Thesis. The bulk of this thesis will be devoted to the historical working-out of the above synopsis. The analytic techniques, and more importantly, the inductive modelling world-view, expanded from statistical specialists to people in other disciplines. In doing so, they not only extended the ability of people in other disciplines to tackle difficult problems, but also helped create and shape which new problems members of those disciplines would find

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(18) Owen M. Fiss, "The Supreme Court 1978 Term; Foreward: The Forms of Justice," 93 Harv. L. Rev. 1, 1979.

important. Insofar as the information technologies contributed to modern developments in the crucial societal realms of law and economics, they are vital to our understanding of important institutions and processes in today's society.

The next chapter will describe the history of information technologies. Chapter III will look at the history of this period in economic thought, and Chapter IV will do the same for legal thought. The fifth and final chapter will outline some of the lessons to be gained from this history. For example, a historical perspective shows the alternatives to thinking in present-day inductive modelling terms. This thesis will use inductive modelling terms often--system, interact, operationalize-- but it would be foolish to believe that this way of thinking, despite its obvious power, offers the uniquely correct way of seeing the world.

7. Note on Historical Method. Anyone attempting a historical analysis can become easily frustrated by the oversimplifications inherent in any short description of the "seamless web" of time. The inductive modelling outlook teaches us that all parts of a system are interconnected, and that therefore precisely demarcated sections of history do not exist.

Georgescu-Roegen uses the troublesome word "dialectics" to describe the way observers should see the world. In his analysis, "inductive" and "deductive" stages might well be

useful and meaningful concepts, yet there would inevitably be an overlap-- a "penumbra"--between the definitions.(19) For example, an early statistician already eager for the collection of experimental data might still not have cast aside his earlier deductive concept of a string-of-beads number line. While recognizing the inevitability of such penumbras, for ease of exposition, this paper will often describe "dialectic" concepts (in Georgescu-Roegen's meaning of the word) as if they were discrete from each other. The goal of careful analysis is to narrow the area of the penumbra.

Another possible objection to the analysis might involve the use of words such as "progress" or "go beyond" to describe the change from one stage to the next. Such words do not in any way imply a teleology, or a ranking of morally preferable world-views. T.S. Kuhn cites Darwin's theory of evolution as the great example of a process without a goal.(20) Much as we never reach the perfect species through evolution, we should not expect our information technologies and the science underlying them to get us to the perfect description of the world. Inductive models provide the ability to exercise ever-greater control over man's environment. However, the discussion in the concluding chapter will show how dangerous that control can be.

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(19) Georgescu-Roegen, chapters 2 and 3.

(20) Thomas S. Kuhn, The Structures of Scientific Revolutions 2nd ed., 1970. p. 171.

8. Evolution from One Stage to the Next. Later chapters will discuss some ways in which progress in information technologies from one stage to the next diffused into other fields such as economics and law. Factors exogenous to the model provided much more of the impetus for that progress, however. For example, in the period under discussion, roughly 1870 to the present, there has been a constant cycle between advances in theory and increased precision of instrumentation-- more exact data highlighted the need for new information technologies, which in turn suggested where to look for new and helpful data. Universities contributed to this cycle by such innovations as land grant universities, technical institutes, and professionalization of research in graduate schools.(21) Industry contributed substantially to the sophistication of information technologies-- by increasing research and development in general, and by their development of many of the management and systems technologies discussed below.(22) Also, The United States Government has helped to speed the evolution, especially through its involvement in military and space research.(23)

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(21) See Frederick Rudolph, The American College and University 1962, esp. Chap. 13, and George H. Daniels ed., Nineteenth Century American Science 1972.

(22) See, e.g., David F. Noble, America by Design: Science, Technology, and the Rise of Corporate Capitalism 1977; and W.H.G. Armytage, A Social History of Engineering 1961.

(23) For a humorous, yet penetrating account of this connec-

Within a less institutional framework, a congeries of phenomena such as urbanization; population rise; increased energy use per capita; increased division of labor; mass marketing techniques; and increased size of the leading corporations have combined to form a more complex personal environment for Americans. Intertwined with these phenomena has been the incredible development of machine technologies. The basic modes of production, transportation, and communication have changed fundamentally. Clearly many volumes could be written in trying to sort out the effects of all these factors on information technologies, economics, and law. This paper will mention these factors, and others like them, as they are pertinent to the discussion.

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tion, see Alfred Blumstein, "The Role of Systems Analysis for Social Problems" pp.4-15 in Alfred Blumstein ed., Symposium on Systems Analysis for Politics 1969.

Chapter II

INFORMATION TECHNOLOGIES AND THE MODEL

1. The Beginnings of Information Technologies. Faced with the myriad details of the histories of information technologies, economics, and law, this paper focuses primariy on only two questions: (a) how does the discipline conform to the model of increasing complexity? and, (b) in what ways does it not conform? The deductive stage of information technologies can only be understood as a lack of such technologies due to the ascendancy of deterministic thinking. The inductive stage began when researchers started to examine carefully the characteristics of particular populations.

Physics offers perhaps the clearest example of the philosophic shift from mechanistic laws to statistical descriptions of random phenomena. Scientists after Newton tried continually to give deterministic explanations of physical phenomena, a tendency apotheosized in Laplace's famous postulation of a demon which could predict the whole future of the universe, given only the positions and momentums of all particles in it at a point in time. However, as natural scientists in the late nineteenth century struggled with the formulation of thermodynamic laws, the huge number of molec-

ules defied their equations. For the sake of computational convenience, the scientists gave up their strict determinism in favor of the methods of statistical mechanics. Later discoveries, such as the random nature of radioactive decay and Heisenberg's Uncertainty Principle, made the use of statistics not simply a convenience, but a philosophical necessity.

Within the realm of information technologies, until the late nineteenth century, the precursors of what we now call statistics lay scattered about the intellectual landscape. These precursors included: the theory of probability, emanating originally from gamblers' odds; demographic studies often drawn from a census of an entire population; the beginnings of actuarial science and insurance; and theories of observations drawn from the natural sciences, especially astronomy.(24)

M.G. Kendall offers the year 1890 as a convenient starting point for "modern statistical developments."(25) Kendall describes an attitude of the period 1890-1910:

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(24) The following account draws heavily on E.S. Pearson and M.G. Kendall, eds., Studies in the History of Statistics and Probability two volumes, 1970, cited as Studies; D.B. Owen, ed., On the History of Statistics and Probability 1976, cited as Owen; and, Statistical Papers in Honor of George W. Snedecor 1972, cited as Snedecor.

(25) M.G. Kendall, "The History and Future of Statistics," in Snedecor, p.199.

> The realization of the necessity of a science of aggregates--whether of human beings, physical objects, errors of measurement, throws of dice, or the weak endings of Shakespeare's verse-- was the unifying theme. The further realization that reasoning about those aggregates was to be conducted in terms of those probabilistic arguments brought in the doctrine of chance....Statistics became, in a sense, part of the science of life, and life itself was seen to be an evolutionary process whose laws could be expressed in statistical terms.(26)

Americans of the time realized the need for statistical laws, but they remained mired in the earlier tradition of statistics. The American Statistical Association (ASA) was formed in 1839, and remained closely tied to Census matters at least through 1918.(27) Under the presidency of the Director of the 1870 and 1880 Censuses, Francis Amasa Walker, the Association grew from its New England roots to a national organization. During his tenure, 1883-1897, the Association expanded its membership to over 500, began to attract prominent academicians, and founded in 1888 the publication which is now entitled The Journal of the American Statistical Association(28) Late nineteenth century statisticians concerned themselves with techniques such as centralizing administration, developing questionnaires, formulating refined definitions of statistical units, and

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(26) Ibid., pp. 199-200

(27) S.N.D.North, "Seventy-Five Years of Progress in Statistics," in John Koren, ed., The History of Statistics: In Memoirs to Commemorate the Seventy-Fifth Anniversary of the ASA, 1918.

(28) Bernard Newton, The Economics of Francis Amasa Walker, 1968, p.151.

improving graphic presentation of data.(29) They did not recognize the relevance of the theoretical statistics being developed in England.(30)

As late as 1918, S.N.D. North of the ASA could survey the field of statistics without mentioning mathematical techniques.(31) North could point, however, to new applications for statistics. Together with the economists and lawyers of the time, discussed below,(32) he reflected the Progressive philosophy of government: "Vital statistics are the foundation upon which rests the modern, humanitarian, scientific movement for the development and application of the laws of public health and sanitation."(33) The increased scope of government action following the breakdown of laissez-faire "enormously widened the field of statistics."(34) The Census remained the fulcrum of progress; North discusses the liberating effect of automatic tabulation in the 1890 Census, the boon to commerce from the new Censuses of Agriculture and Manufacturing in 1900, and the establishment of a Permanent Census Office in 1902.(35)

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(29) Newton, p.152.

(30) See the next section for those developments.

(31) S.N.D. North, p.15-52.

(32) Infra, Chap. III, sec. 5; Chap. IV, sec. 4.

(33) Ibid., p.30.

(34) Ibid., p.21.

(35) Ibid., pp.26-28.

Techniques developed for the Census spread to businesses. The annual reports of Chambers of Commerce and Boards of Trade provided trustworthy local data. Trade journals proliferated, and daily newspapers began to publish extensive statistics of commerce and trade. Actuarial science flourished, as life insurance policies increased almost a hundredfold from 1860 to 1910, and industrial insurance over twentyfold from 1885 to 1910. In summing up, North says statistics "are the basis of the new science of Efficiency [sic], which is working a revolution in industrial methods."(36)

2. The Rise of Mathematical Statistics. Meanwhile, the mathematical underpinnings of this new science of Efficiency were being developed in England. The first wave of advances arose primarily from work in biometrics, and to a lesser extent, from economics. Karl Pearson, W.F.R. Weldon, and the Galton Laboratory proposed theories of correlation and curve fitting, created the chi-squared test, and produced several important mathematical tables. Pearson helped found the still-prominent journal Biometrika in 1901. W.S. Gosset of Guinness Breweries derived several theoretical contribu-

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(36) All the above from North, pp.36-38. The insurance totals are reported as: life insurance $163,703,455 in 1860, $13,227,213,168 in 1910; industrial insurance $145,938,241 in 1885, and $3,177,047,874 in 1910. North's brazenness in publishing eleven significant digits, and his pride in their supposed exactness, is one indication of the unsophistication of the mathematics of the time.

tions from his industrial experience, notably his "Student's" t distribution for estimating the standard deviation of a small sample(37)

A second wave of advances in Britain followed in the wake of R.A. Fisher. In the 28 years following his first article, in 1912, Fisher wrote over over 180 articles and books, including his 1925 Statistical Methods for Research Workers, described in 1965 as "one of the standard texts" of statistics.(38) Drawing upon field experiments in agriculture, Fisher and his associates learned to handle mathematically the analyses of experiments subject to the many variations of weather, soil conditions, human treatment, and other factors. Besides his improvements in mathematical rigor, Fisher developed the analysis of variance approach, and many improvements in experimental design. He also authored seminal papers on several other statistical problems. His use of randomization in the design of experiments had particularly far-reaching consequences, as did his attempts at multivariate explanation--the necessary precondition for inductive modelling.

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(37) First published in 6 Biometrika 1, 1908. For a biography and bibliography of Gosset, see pp. 355-403 in Vol. I of Studies.

(38) Studies, Vol II,p.440. A biography and bibliography of Fisher is in Studies, Vol I, pp.439-453.

Udny Yule was another important contributer to the growth of mathematical statistics. Yule, who studied under Karl Pearson, developed the theory of time-series, which investigates the behavior of a variable over time. In a 1926 article, Yule introduced to the West a stochastic term in the series; that is, he postulated a probabilistic relation between variables, and not either an independent or deterministic one.(39) Such time-series were essential for the dynamic modelling of the third stage.

Jerzy Neyman and Karl Pearson's son Egon collaborated between 1927 and 1934 on work derived in large measure from Fisher. They created the techniques of hypothesis testing and confidence intervals, which became very useful tools for decision-making. With the addition of a 1934 Neyman paper on sample surveys of finite populations,(40) their work helped complete the theoretical preparation for third-stage technologies. At the onset of World War II most statisticians in England had assimilated these new mathematical techniques. Their counterparts in the United States, how-

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(39) G. Udny Yule, "Why do we sometimes get nonsense correlations between time-series? A study in sampling and the nature of time-series." 89 J. Roy. Statist. Soc. 1, (1926). For a biography and bibliography of Yule, see Studies, Vol. I, pp. 418-425. Markov and Slutzky in the Soviet Union had earlier, independently of Yule, described stochastic time-series.

(40) Jerzy Neyman, "On the two different aspect of representative method: the method of stratified sampling and the method of purposive election." 97 J. Roy. Statist. Soc., 558-606, (1934).

ever, were only beginning to catch up with their British associates.

3. Mathematical Statistics in the United States. While English statisticians as early as 1890 avidly explored mathematical statistics, Americans lagged behind. College courses on statistics had existed since the time of Francis Amasa Walker,(41) but few professors of mathematical statistics emerged until the end of World War I.(42)

By 1920, a substantial number of researchers in fields including biology, animal husbandry, and economics had learned methods of linear regression and multiple correlation largely drawn from the Galton Laboratory.(43) However, the necessity of doing all calculations by hand considerably reduced the power of those methods. Despite first attempts to develop and program calculating machines,(44) the slow-

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(41) Walker taught a course on "The Statistics of Industry" at Yale in 1873-74, Newton,p.151. For a description of early efforts to include statistics in the college curriculum, see Paul Fitzpatrick "Leading American Statisticians of the Nineteenth Century," 52 J.Am.Stat.Assoc. 318-319.

(42) Boyd Harshbarger, "History of the Early Developments in Modern American Statistics," pp. 133-145 in Owen. Harshbarger mentions H.L.Rietz at Iowa (1918), Harry Carver at Michigan (1915), and George Snedecor at Iowa State (1915) as among the first.

(43) Jay L. Lush "Early Statistics at Iowa State University," in Snedecor, p.212.

(44) Described in a now-rare 1925 bulletin by George Snedecor and Henry Wallace on "Correlating and Machine Calculation."

ness of calculations remained a barrier until the post-World War II development of the computer.

Acceptance of Fisher's statistical inference did not come until after 1930. One lonely call, at least initially, for rigorous mathematics was Harry Carver's The Annals of Mathematical Statistics, begun in that year.(45) Fisher's visits to Iowa State University in the summers of 1931 and 1936 helped to dramatize the need for better experimental design in a variety of disciplines. As late as 1937, however, the Census Bureau's introduction of inferential sampling techniques was considered untrustworthy by Congress.(46) Mathematical statistics did not gain general acceptance until during and after World War II when the generation of young mathematical statisticians trained by pioneers such as Carver and Reitz matured.

4. The Inductive Modelling Stage. The early concentration of American statisticians' interest on the census obviously did not arise from a deductive world-view; as North described, industry and government used a great deal of specific data as an aid to decision-making. However, in terms of the model of increasing complexity, this period corresponds to the deductive first stage in several important res-

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(45) Jerzy Neyman, "The Emergence of Mathematical Statistics," in Owen, pp.171-174.

(46) Morris H. Hansen and William G. Madow, "Historical Development of Sample Surveys," in Owen, p.87.

pects. Use of a census or other statistics, as witnessed by the insurance figures quoted above, implied a string-of-beads number line. Statisticians, in their attempts to chronicle a population to the last digit, still treated data as if society conformed to exact measurement.

With the importation of mathematical statistics from England came the true inductive phase. The new techniques of experiment design and sample surveys for the first time set mathematical standards for how to move from specific data to general conclusions about a population. The foundations of today's information technologies were complete by the mid 1950's. The development of the inductive modelling techniques received a great impetus from the outbreak of World War II. As before, the first advances happened in England.

In 1937 a research team working on England's antiaircraft system began experimenting on how best to fit radar into what we now call a "total system" of defense. This group of Royal Air Force and Air Ministry scientists came together from several disciplines into a new "operational research" unit.(47) During the war, operations research became a multi-purpose tool. The military used it, for example, to

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(47) This early history of the field comes from Philip M. Morse, "The History and Development of Operations Research," in Grace J. Kelleher, ed., The Challenge to Systems Analysis: Public Policy and Social Change, 1970, pp. 19-27. The English have preserved the name "operational research," while Americans usually say "operations research."

improve the fit between weapons and their human operators, to analyze the probable best choice among alternative tactics and strategies, and to improve the efficiency of organizations in the achievement of their goals of supply, combat, etc. By the end of the war, "there was no major Allied command without an operational group."(48) After the war, the approach spread to industry, and the Operations Research Society began in 1952. Philip Morse wrote in 1970:

> Operations research has emerged as a unified field of applied study by its combination of measures of effectiveness, justified by operational experiments, with mathematical models for predicting the efficiency of future operations, all designed to influence policy.(49)

Similar to operations research is cybernetics, a name coined by Norbert Wiener in 1948. Wiener defines cybernetics as "the entire field of control and communication theory, whether in the machine or in the animal.(50) The term stems from the Greek word for "steersman," and refers in particular to a basic concept of the field--the feedback loop. This concepts describes the "feeding back" of part of the output to the input in order to control the future output. For example, when a household thermostat becomes too hot, the more heat-sensitive metal will bend, and the thermostat will press a valve and bring the output of the heat back into equilibrium, or homeostasis as it is often called

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(48) Ibid., p. 23.

(49) Ibid., p. 23.

(50) Norbert Wiener, Cybernetics, 1st ed., 1948, p. 19.

in the field.

James Clerk Maxwell is usually given credit for first discussing the feedback loop in 1868,(51) but H. Nyquist performed the first modern analysis of feedback systems in his 1932 article "Regeneration Theory."(52) The importance of the concept became much greater after Wiener, however, as it was generalized beyond communications theory and became a building block of systems analysis.

Wiener emphasized the necessity of bringing together scientists of many disciplines; he believed "the most fruitful areas for the growth of the sciences [are] those which [have] been neglected as a no-man's land between the various established fields."(53) As a leader of the inductive modelling movement toward an interconnected network rather than a string-of-beads number line, Wiener strove constantly to recognize the similarities of disparate fields. For instance, both neurophysiology and communications engineering face problems of measuring and responding quickly to potentially disruptive information-- e.g., a noxious stimulus or a radio wave going out of synchronisation.(54) By

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(51) E.g., by Nasli H. Choksy, "Feedback and Stability," in C.D. Flagle, W.H. Huggins, and R.H. Roy eds., Operations Research and Systems Engineering, 1960, p. 705. J.C. Maxwell, Proc. Roy. Soc., March 5, 1868.

(52) Discussed in Choksy, p. 706. H. Nyquist, "Regeneration Theory," 2 Bell System Technical Jl., 126, 1932.

(53) Wiener, p. 8.

studying these disciplines, Wiener suggested better ways to build computers, which also had to handle great amounts of information quickly with sufficient checks (in the form of feedback loops) on accuracy. Improved computers could then help solve similar problems of responding to stimuli in other fields.

The general applicability of the computer lent support to the general systems theory proposed by Ludwig von Bertalanffy and others. Derived from the biology of the organism (in contrast with the biology of component parts) general systems theory emphasized the concept of synergy-- that the whole is greater than the sum of its parts. The principles of the theory became known in the United States after World War II, and in 1954 the Society of General Systems Research was organized, with the following charter:

> Major functions are to (1) investigate the isomorphy of concepts, laws, and models in various fields, and to help in useful transfers from one field to another; (2) encourage the development of adequate theoretical models in the fields which lack them; (3) minimize the duplication of theoretical efforts in different fields; (4) promote the unity of science through improving communications among specialists.(55)

The fields of operations research, cybernetics, and general systems theory all emerged soon after World War II. Proponents of each often claimed their approach to be the

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(54) Ibid., Introduction, pp. 7-39.

(55) Quoted in Ludwig von Bertalanffy, General Systems Theory: Foundations, Development, Applications, 1968, p.15.

most generally applicable, and tried to subsume the others.(56) In retrospect, the similarities of approach outweigh the differences. All of the fields drew heavily on the statistical techniques developed before the war. Mathematical statistics in the United States ceased to be controversial once methods such as quality control by sampling and operations research became routine in industry and the military.(57) The fifteen years after the war saw an incredible blossoming of many techniques for handling inductive models. Some of the new fields, and their starting dates, are: game theory (1944);(58) decision theory (1947);(59) and information theory, which is closely tied to cybernetics (1949).(60) Of course, consistent with the third-stage concept of an interconnected system, any boundaries between such fields are somewhat "dialectic" and arbitrary.(61)

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(56) See, e.g., L. Eugene Root on operations research in Kelleher, p.6; Wiener, pp. 26-27; and von Bertalanffy, p. 15.

(57) See Owen, chapters 12, 18, 20, and 21.

(58) John von Neumann and Oskar Morgenstern, Theory of Games and Economic Behavior, 1944.

(59) A. Wald, "Foundations of a general theory of sequential decision functions," 15 Econometrica 279, 1947.

(60) Claude Shannon and Warren Weaver, The Mathematical Theory of Communication, 1949.

(61) See supra Chap. I, sec. 7.

Newly-funded researchers developed specific techniques within the several theories described above. George Dantzig discovered the simplex algorithm for linear programming in 1947. The Monte Carlo methods for stochastically evaluating a mathematical formula were generally known by 1954.(62) Information technologists also made other advances: improved matrix modelling, dynamic programming, and computer and gaming simulation. The Army Corps of Engineers began the use of cost/benefit analysis, drawing on many of these technologies in its attempts to quantify the values involved in public decision-making.(63)

Information technologies have grown apace since 1950. Laurence Tribe describes this growth as the triumph of "instrumental rationality"-- "the selection of efficacious means to previously given ends."(64) Within the inductive models, ends are usually described operationally in the form of constraints, or parameters, on the crucial variables. For example, important variables in the construction of a guided missile might include: cost in dollars; time in days necessary for manufacturing; and reliability in per cent breakdown within a year for each of the many subsystems.

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(62) H.O. Hartley, "The Impact of Computers on Statistics," p. 431 in Owen.

(63) Eldridge Adams, Courts and Computers, 1972, pp.85-86.

(64) Laurence H. Tribe, "Technology Assessment and the Fourth Discontinuity: The Limits of Instrumental Rationality," 46 S.Cal.L.Rev. 617,660 (1973).

Given acceptable levels for each parameter, the inductive modelling techniques then carry out the science of Efficiency to a degree far beyond the 1918 dreams of S.N.D. North. The progress of instrumental rationality approaches the engineer's ideal of objectivity-- to optimize, to maximize, and to sanitize, but not to humanize.

Chapter III

ECONOMIC THOUGHT AND THE MODEL

1. Introduction to the History of Economic Thought. The twentieth-century history of information technologies has shown a fairly steady advance in the ability of researchers to describe and analyze complex systems. Inductive models have subsumed the techniques of the earlier stages. In economics, however, the substitution of second- and third-stage thinking for deductive thinking is not nearly so complete. The latter stages of the model have grown alongside the the continuing strong tradition of more deductive-minded libertarians such as Milton Friedman. This chapter, therefore, cannot describe the triumph of the latter stages so much as chronicle their appearance first as avant-garde and later as increasingly reputable alternatives to the neoclassicist tradition.

This chronicle, also, cannot pretend to include all of the many important economic movements in American history. Joseph Dorfman, in his five-volume Economic Mind in American Civilization,(65) counts over 150 economists important enough to deserve mention in his tables of contents. Many

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(65) Joseph Dorfman, Economic Mind in American Civilization 1946-1959. Cited as Dorfman (a).

of these economists, whatever their other achievements, did not contribute significantly to the development of the model of increasing complexity. To take one notable example, Karl Marx, despite his worldwide following, did not affect the model, and so he will not be discussed here. The remainder of this chapter, then, will selectively treat those economists who did affect the model.

2. Laissez-Faire Unlimited. In the golden age of classical economics, running roughly from the publication of Adam Smith's Wealth of Nations in 1776 until 1870, the laissez-faire precepts of such European economists as Smith, Thomas Malthus, David Ricardo, and Jean-Baptiste Say became "so long accepted and so often reiterated that they had the character of a tradition."(66) While the leading theorists lived in Europe, men such as Jacob Newton Cardozo and Henry C. Carey spread the tradition to the United States.(67) Their teachings included: the use of the individual as the appropriate unit of analysis; Say's law that demand will always match the available supply (i.e., that the market always tends to long-run equilibrium with no unemployment)(68) ; and the belief in the objective, natural-law character of economic theories, as exemplified in Carey's

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(66) Ibid., Vol III, p.82.

(67) Ibid., Vol II, pp. 551-565 for Cardozo; pp. 789-804 for Carey.

(68) For ease of exposition, modern terms will be used here to describe the concepts of earlier economists.

1836 title, The Harmony of Nature, as Exhibited in the Laws Which Regulate the Increase of Population and the Means of Subsistence. This natural law approach matched the economists' desire to equal in the social sciences Newton's achievements in the physical sciences.

Economics was still far from a deterministic understanding of society, however, particularly in the United States, with its agrarian population, its lack of cultural centers to provide leisure for scholarly speculation, and its distrust of the elitism of higher education. This pragmatic tendency kept Americans from accepting some of the most extreme abstractions of classical economics. For example, in 1835, four years before the birth of the American Statistical Association, Carey's Essay on the Rate of Wages included a description of forty years of statistics measuring the relative change in wages, food prices, and clothing prices. Carey used these statistics because he believed they supported the "law of harmony-of-interests"; as Dorfman writes of Carey: "No one was so gifted or persistent in arguing that a free hand to large business--more accurately, to promoters-- helped farmers, laborers, and small businessmen, and prevented a moneyed aristocracy."(69)

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(69) Ibid., Vol II, p. 790.

By claiming such harmony-of-interest, classical economics(70) successfully legitimized the businessman's quest for profit, and speeded the breakdown of traditional mercantilist restrictions on free trade. Such a breakdown included great changes in the legal structure. The next chapter will discuss the huge impact of laissez-faire on the American conception of property. In economics, the emphasis on individuals best serving society by pursuing their own profit created a prejudice against government intervention which persists today.

3. The Breakdown of Classicism. However well the classical model described the atomistic competitors of 1820's England, by 1870 intellectual and social dissatisfaction had contributed to the rise of two new schools-- the marginalists led by (among many others) the Englishman William Stanley Jevons, and the German historical school of Gustav Schmoller and others. The marginalists ratified the nineteenth-century, laissez-faire triumph of the bourgeoisie. The historicists, in contrast, tended toward government intervention and recognition of the rights of other classes in society.

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(70) For excellent capsule summaries of the major economic schools, see Jacob Oser and William C. Blanchfield, The Evolution of Economic Thought, 3rd ed., 1975.

By supporting landowners and capitalists with supposedly impartial theories, the marginalists greatly aided the status quo.(71) They defended landowners by replacing Ricardo's theory of "unearned" rent based on the theory of diminishing returns,(72) with a new theory that rent on land is equivalent to interest on capital, and thus simply a return on the entrepreneur's investment. They protected businessmen by renouncing the labor theory of value propounded by Ricardo and Marx and replaced it with the theory of exchange value based on the utility and scarcity of a product, as determined by market forces.(73)

Jevons' use of the differential calculus was the source of the name of this marginalist school-- he set the marginal utility of a good equal to its price at equilibrium. The marginalists' use of mathematics included, in addition to calculus, several new types of graphical analysis, and also the explicit listing of premises in accordance with the deductive stage of our model. Such mathematization contributed to the "natural laws" attitude of economists, and to the reaction against radical violations of those laws such as labor unions, socialism, and government intervention.

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(71) This school, like all others, contained differences of opinion around the norm. See, e.g., Ingrid Hahne Rima, Development of Economic Analysis 3rd ed., 1978, Part III, "Marginalism," pp. 203-309.

(72) See,e.g., Oser and Blanchfield, pp. 93-99.

(73) See Rima, pp. 223-228 for Jevons' theory of value.

The mathematization and abstraction from practical problems became so extreme that "by the end of the nineteenth century, the public, and especially the businessman, could no longer understand economists."(74)

The Frenchman Leon Walras constructed the most abstract of these deductive models in the general equilibrium analysis laid out in his Elements of Pure Economics (1874).(75) Walras described a massive set of equations for the economy that even modern computers cannot solve. General equilibrium analysis illustrates the marginalists' tendency to care more for the elegance of the mathematical structure than the possibility of operationalization of the model.

In contrast, the historicists advocated an inductive economics. Dorfman, in his article "The Role of the German Historical School in American Economic Thought."(76) discusses the opinions of the American historicist E.R.A. Seligman:

> The chief point of difference was that the orthodox had an atomistic, individualistic point of view; the other [the historicists] had a social standpoint. The orthodox posited the universal spirit of self-interest; the other stressed the "multiplicity of motives which cannot be jumbled

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(74) Joseph Finkelstein and Alfred L. Thimm, Economists and Society 1973, p. 161.

(75) Ibid., pp. 194-204 contains a readable mathematical explanation of Walras' system.

(76) Joseph Dorfman, "The Role of the German Historical School in American Economic Thought," 45 Am.Econ.Rev. 17, May 1955. Cited as Dorfman (b).

> together in the phrase, desire for wealth." It emphasized, also, the importance of legal systems and historical causes and the close connection between ethics and economics as sister social sciences.(77)

Writing in the wake of Darwin's Origin of Species (1859), the American historicists believed in the evolution of institutions as social beings, analogous to the evolution of species. They felt economists should take those institutions as the proper unit of analysis. Only an inductive historical investigation of the many factors which determine institutional form can lead to correct historical understanding. Simon Nelson Patten wrote: "The objective [economic] laws of a given society are not simply the laws of nature; they are laws derived from the particular combination of natural forces of which society makes use."(78)

The establishment of the American Economic Association (AEA) in 1885 marked the high point of the historicist revolt against the classicists. Many of the historicists involved with the AEA had attended universities in Germany,(79) and they came back eager to do battle with "the

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(77) Dorfman (b), p.27. Seligman's quote is from his article "Sidgwick on Political Economy," the Index, August 16,1883, pp. 75-76.

(78) Quoted in Sidney Fine, Laissez-Faire and the General-Welfare State: A Study of Conflict in American Thought, 1865-1901 1956, p. 242. From S.N. Patten, The Theory of Dynamic Economics 1892, pp. v-vi.

(79) Dorfman (b). They included: Richmond Mayo-Smith, Simon Nelson Patten, Henry Carter Adams, Richard T. Ely, E.R.A. Seligman, and John Bates Clark.

regnant extreme individualism of the eighties."(80) The choice of Francis Amasa Walker as first president reflected a somewhat moderate move toward the inductive stage. The election of the then-president of the American Statistical Association signaled a new interest in empirical work. At the same time, Walker's credentials as an establishment economist and president of M.I.T. showed the historicists' willingness to compromise with the marginalists in the interests of promoting the organization.

After a tumultuous series of meetings in 1885,(81) the AEA voted a statement of principles which toned down earlier direct attacks on laissez- faire, yet which maintained a distinctly unorthodox tone. The first of these principles said: "We regard the state as an agency whose positive assistance is one of the indispensable conditions of human progress." Such a statement contradicted the very roots of laissez-faire (which in French means "leave be") by asserting that the state should not "leave be."

The second principle discussed inductivism: "We believe that political economy as a science is still in an early stage of its development. While we appreciate the work of former economists, we look not so much to speculation as to the historical and statistical study of the actual condi-

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(80) Dorfman (a), Vol III, p. 205.

(81) Described in Fine, pp. 215-221.

tions of economic life, for the satisfactory accomplishment of that development." [emphasis added.] This basic statement of the historicist position contains a pointed jibe at the other school; "speculation" can hardly be the basis of the serious business of allocating resources.

The third principle attacked the classical idea of harmony-of-interest discussed above in connection with Carey: "We hold that the conflict of labor and capital has brought into prominence a vast number of social problems, whose solution requires the united effort, each in its own sphere, of the church, of the state, and of science." One problems was that the large corporations could exercise their monopsony power in the labor market so as to keep wages artificially low. Several historicists violated conventional academic wisdom by actively supporting labor unions and factory legislation as correctives for that power.(82)

The fourth and final principle stated: "In the study of the industrial and commercial policy of governments we take no partisan attitude. We believe in a progressive development of economic conditions, which must be met met by a corresponding development of legislative policy." [emphasis added] This statement expanded on the first principle by calling for a "progressive" legislative program by the

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(82) E.g., H.C. Adams, "Relation of the State to Industrial Action," 1 A.E.A. Publications 511, 1887, and R.T. Ely, Monopolies and Trusts 1900.

state, and in fact, as discussed below,(83) historicists eventually contributed to the Progressivism of the early twentieth century.(84)

4. The Neoclassical Synthesis. The original AEA statement of principles, therefore laid out an inductive, historical, progressive program which matches well the inductive stage of our model. However, quite soon after the birth of the AEA, older and more marginal men succeeded in toning down the language of the original proposals. In 1887 a new constitution spoke only of "the encouragement of economic research, especially the historical and statistical study of the actual conditions of industrial life."(85) Guided by President Walker's statements about the complementary nature of marginalism and historicism, by 1890 almost all of the leading academics had joined the organization.(86) At that time, economics had become much more professionalized. In addition to the establishment of the AEA, the late 1880s saw the birth of several important professional publications: the Quarterly Journal of Economics, the Political Science Quarterly, and the Annals of the Academy of Political and Social Science. The AEA itself published a number of mono-

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(83) Infra, Chap. III, sec. 5.

(84) See, e.g., the discussion of J.R. Commons in Sec. 5 below.

(85) Dorfman (a), Vol III, p. 208.

(86) Ibid., p. 208.

graphs and reports. The number of college courses was growing, as evidenced by the increased sales of textbooks such as Walker's Political Economy (1883).(87) When historicist Richard Ely stepped down from the secretaryship of the AEA in 1892, the "new synthesis" of the marginalists controlled the organization.(88)

Englishman Alfred Marshall's Principles of Economics (1890), and American John Bates Clark's The Distribution of Wealth (1899) became the centerpieces of the new synthesis. Both writers incorporated elements of classicism, marginalism, and historicism into a synthesis usually known as neoclassicism. Marginal analysis of partial equilibrium economic problems dominated neoclassicist discussion, but a trace of historicism remained. As Dorfman describes the synthesis, it conformed exactly to the inductive stage: "doctrinaire individualism was modified or corrected by the encouragement of the powers and functions of a great many aggregates."(89) Given the obvious inexactitude of economic measurements,(90) once empiricism entered economics in a

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(87) Bernard Newton, The Economics of Francis Amasa Walker 1968, p. 12.

(88) Fine, p. 221.

(89) Dorfman (b), p. 28.

(90) For an excellent introduction to the method and limitation of method in economic analysis, see Ian M.T. Stewart Reasoning and Method in Economics 1979, especially Chap. 8 on "Accuracy and Error in Applied Economics."

professional way through the AEA, the second-stage number line of a population distributed around a mean (in the quote, the use of aggregates to correct for doctrinaire individualism) replaced the string-of-beads number line of early laissez-faire.

In the decades following this successful synthesis, however, many neoclassicists emphasized the more deductive aspects of Marshall's and Clark's theories. Equipped with their new mathematical tools, neoclassicists retained the marginalist belief in the deductive ideal of pure competition between atomistic firms. Marshall's graphic techniques offered visible "proof" to students and politicians that such a market maximized efficiency. Neoclassicists also concerned themselves primarily with the theoretical workings of markets, and not so much with whether or not those markets actually worked. For instance, Irving Fisher developed theories of the capital market,(91) and Frank William Taussig, editor of the Quarterly Journal of Economics, did the same for the labor market.(92)

Clark himself outlined the ideas that later became the core of welfare economics, the eventual neoclassical method of inductive economics. In 1882 Clark described "inappropriable utilities," which correspond to the spillover

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(91) The Rate of Interest 1907, and its grand successor, The Theory of Interest 1930.

(92) Wages and Capital, 1896.

effects, or "externalities," examined rigorously by Pigou in 1920. Clark used as his example the question of why the community should give tax exemptions to schools and churches. Since tuition and church offerings comprise the only revenues of those worthy institutions, without some form of interference by government, the market would not provide the highest utility to the community. Part of the utility was "inappropriable"--general to the whole community--and thus would not be taken into account by individuals reckoning only their personal utility.(93)

The neoclassical allowances for market imperfections did not become prominent until after 1920. Clark's idea of inappropriable utilities seems to have disappeared amidst the turmoil among academics in the 1880s. In 1920 Arthur C. Pigou, the successor to Marshall's chair of political economy at Cambridge, rediscovered Clark's theory. In that year he published The Economics of Welfare, in which he discussed economic welfare, defined as "that part of social welfare that can be brought directly or indirectly into relation with the measuring-rod of money."(94) Pigou laid the mathematical foundations for an attack on the correctness of market-based determinations of price. He distinguished between private and social marginal costs and benefits, and cited numerous cases in which individuals acted for their private

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(93) Described in Dorfman (a), Vol III, p. 192.

(94) Quoted in Oser and Blanchfield, p. 413.

benefit at the expense of social benefit. This new distinction,(95) led logically to a new interventionist role for government, usually in the form of taxes designed to eliminate the externality. Conceptually, welfare economics corrected the exact determination of price in the market by describing a distribution of possible prices around the market price, depending on the degree of externality--an inductive-stage approach.

Two books appeared in 1933 which complemented Pigou's mathematical elaboration of market imperfections: Harvard professor Edward H. Chamberlin's Theory of Monopolistic Competition and Cambridge professor Joan Robinson's Economics of Imperfect Competition. Although the theory of monopoly itself traces back to Augustin Cournot in 1838,(96) Chamberlin and Robinson used impeccable mathematical technique and graphical analysis to fill in the range between pure monopoly and pure competition. Both writers accepted the basic assumptions of neoclassical economics, and extended the old monopoly theory concept of a firm's declining marginal revenue to show why a monopolistic firm would produce below the optimal level for society. Their sweeping extension of monopoly theory provided an important theoretical

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(95) Henry Sidgwick made a similar distinction in The Principles of Political Economy 1893, but not until Pigou did the idea become widely accepted. Discussed in Rima, p. 320.

(96) The following account is drawn from Oser and Blanchfield, pp. 300-314.

justification for the empirical examination of markets--the need to discover the degree of market imperfection. With these new theoretical tools, the neoclassicists prepared themselves for inductive models based on mathematics and a heavy dose of statistical data.

5. The Heirs of Historicism: The Institutionalists and the Growth of Statistical Research. While neoclassicists took until the 1930s to realize the limitations of partial equilibrium analysis based on pure competition, the heirs of historicism made many similar criticisms before 1900. This group of economists, often called the institutionalists, achieved growing respect through the writings of three men: Thorsten Veblen, Wesley C. Mitchell, and John Rogers Commons. Veblen came first, and his vitriolic attacks on neoclassicism entirely forswore marginalist market analysis in favor of an inductive and anthropological study of institutions.(97) His books, such as The Theory of the Leisure Class (1899) and The Theory of the Business Enterprise (1904), provided fertile ground for later critics of neoclassicism,(98) but his difficult personal manner and the extreme nature of his writings prevented his acceptance by the contemporary economists.(99)

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(97) For a look at the life and ideas of this troubled man, see Douglas F. Dowd, Thorsten Veblen 1964.

(98) See Dorfman (a), Vol IV, p. 358.

(99) Dorfman (a), Vol III, describes Veblen as "standing halfway out of society," (p. 438) and talks of his

In contrast, Veblen's outstanding pupil, Wesley C. Mitchell, became "recognized as one of the nation's most farsighted economists"(100) in the course of his lifelong advocacy of improvements in empirical research. Mitchell used statistical and historical research in his doctoral dissertation,(101) and improved them for his best-known work, Business Cycles (1913). His recognition of the importance of business cycles (a phenomenon not accounted for by the neoclassicists, who accepted Say's Law) convinced him of the need for progress at the level of macroeconomic research. In keeping with his institutionalist beliefs, Mitchell involved himself in public affairs: he helped establish the short-lived Central Bureau of Planning during World War I; he founded the National Bureau of Economic Research in 1920; and, at President Hoover's request, he led the compilation of the two-volume Recent Economic Changes in the United States in 1929, which "helped supply the basic factual foundation heretofore not available for national policy determinations."(102)

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style of writing "in the terse impersonal manner of a man from another planet." (p. 446).

(100) Dorfman (a), Vol IV, p. 36. Dorfman (a) gives an excellent short biography of Mitchell, Vol III, pp. 455-473, and Vol IV, pp. 360-377.

(101) A History of the Greenbacks with Special Reference to the Economic Consequences of Their Issue: 1862-1865 1903; He expanded the history in his Gold, Prices, and Wages Under the Greenback Standard 1908.

(102) Dorfman (a), Vol IV, p. 373.

John Rogers Commons went beyond Mitchell in his application of institutional economics to the formation of government policy.(103) While a professor at the University of Wisconsin, Commons drafted a number of progressive laws.(104) Additionally, Commons became the foremost American labor economist with his supervision of A Documentary History of Industrial Society (1910-1911), and of the History of Labor in the United States (1918). Based on these books, he developed in his later writings(105) theories of bargaining which used for the first time such dynamic terms as "transactions" and "collective bargaining" as means of analysis within an institutional setting. His substitution of such process terms (in place of the static equilibriums of the neoclassicists), and his perception of the interrelated nature of society's many institutions,(106) combined to bring him close to the inductive model stage. On a practical level, through his many writings and his successful students,(107) Mitchell "provided the New Dealers with a

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(103) For a biography of Commons, see Dorfman (a), Vol III, pp. 276-294, and Vol IV, pp. 377-395.

(104) These included, for the period 1904-1921: a civil service law; a bill providing for state regulation of public utilities; a draft of a workmen's compensation law; a minimum wage law for women; and an improved child labor law. Described in Oser and Blanchfield, p. 385.

(105) Especially, Legal Foundations of Capitalism 1924, and Institutional Economics 1934.

(106) Discussed in Oser and Blanchfield, p. 386.

(107) These students included such eventual New Dealers as

considerable number of practical instrumentalities and devices, as well as experienced personnel, to direct the new agencies of regulation and administration."(108) Within the context of the empirical recommendations of institutionalism, the period 1900-1935 witnessed other significant and growing set of inductive institutions and techniques. Isaac Rubinow, "the father of the social insurance movement in the United States," oversaw the development of actuarial tables which eventually formed the statistical basis for workmen's compensation and social security.(109) Correa M. Walsh (1901) and J. Pease Norton (1902) contributed to the study of index numbers and time series, respectively.(110) The use of index numbers expanded sharply after the Bureau of Labor Statistics commissioned Mitchell to write The Making and Use of Index Numbers (1917). The Bureau began the cost-of-living index (now called the Consumer Price Index) in 1921, and numerous other indices were developed during the next decade.(111) The collection and aggregation of unemployment, monetary, and industrial statistics increased. As discussed

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Selig Perlman, Arthur J. Altmayer, and Edwin E. Witte. Dorfman (a), Vol IV, pp. 395-398.

(108) Dorfman (a), Vol IV, p. 398.

(109) Ibid., p. 116.

(110) Correa M. Walsh, The Measurement of General Exchange-Value 1901, and J. Pease Norton, Statistical Studies in the New York Money Market 1902. Cited in Dorfman (a), Vol III, p.353.

(111) This account follows Dorfman (a), Vol IV, pp. 200-208.

in the previous chapter,(112) correlation techniques based on this new wealth of data became common in the twenties, but economists often did not know how to apply them properly.(113)

Fortunately, institutions were developing to correct for such overenthusiastic use of statistics. Harvard's Committee on Economic Research began publishing the Review of Economic Statistics in 1918. Other new institutions, and their year or origin, included: The National Industrial Conference Board (1916); The New School for Social Research (1919); Mitchell's National Bureau of Economic Research (1920); Stanford's Food Research Institute (1921); and the Institute for Economics (later the Brookings Institute) (1922). As discussed in the previous chapter,(114) instruction in mathematical statistics developed during the interwar years, and this trend also contributed to the quality of economic research.

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(112) Supra, Chap. II, sec. 3.

(113) As one Englishman observed in 1929, "American workers [are] altogether too prone to make extensive calculations without sufficient regard to the reliability or adequacy of the data used and the logical significance of the factors considered or without adequate analysis of the significance of the results obtained." Quoted in Dorfman (a), Vol IV, pp. 206-207.

(114) Supra, Chap. II, sec. 3.

6. The Inductive Modelling Stage: Econometrics and Input-Output Analysis. The previous two sections have traced two largely independent lines of thought which converged toward the inductive model stage in the period just before World War II. The neoclassicists, following the work of Pigou, Chamberlin, and Robinson, had derived from their mathematical models the need for inductive research into market imperfections. Coming from the opposite direction, the institutionalists had created a huge mass of empirical data, and faced the task of processing that data through their new research institutions. With the coming of the Great Depression, businessmen and microeconomists became desperately aware of the need for highly effective management tools. The experience of the thirties cleared the way for the post-war acceptance of inductive modelling technologies such as operations research and linear programming. At the same time, the Depression convinced many people of the importance of business cycles; this realization prompted many large businesses to develop their own inductive techniques for modelling the changing economy, and it gave government the rationale for eventually constructing its own models for planning purposes.

The much-trumpeted Keynsian revolution of the thirties did not contribute directly to these evolving inductive model world-view. Apart from the historians' debate over how much Keynes actually influenced Roosevelt,(115) Keynes,

despite the important policy implications of his work, did not challenge many of the psychological and epistemological underpinnings of the neoclassicists. He retained a basically static description of simple-causality, two-variable models (e.g., interest rate vs. investment) based on the assumption of profit-maximization and did not even challenge most of the microeconomic theories of his predecessors. His analysis applied only to the "ultra-short run" and did not pretend to solve the difficulties encountered once the demand-stimulation policies soaked up the excess capacity.(116) Keynes' chief contribution to our model was the legitimacy that his model accorded government intervention. Because habits of governement intervention in the thirties paved the way for the later use of econometric planning after World War II, the Keynsian revolution did contribute indirectly to acceptance of the model of increasing complexity.

The major macroeconomic manifestations of the inductive model were econometrics and its close relative, input-output analysis.(117) The Norwegian economist and statistician Ragnar Frisch coined the term "econometrics" in 1926. The term

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(115) See Arthur J. Schlesinger, Jr., The Politics of Upheaval 1960.

(116) For a critical analysis of the Keynsian, short-run approach, see Finklestein and Thimm.

(117) The microeconomic development of operations research was discussed supra, Chap. II, sec. 4.

literally means the "measurement of economics," and refers in practice to the use of systems of mathematical equations, often time-series, which together predict the future values of variables given initial parameters. Frisch spread the idea to the United States during a 1929 visit to Yale, and he helped found the journal Econometrica the following year, in collaboration with several Americans. In 1939, Jan Tinbergen, working in Holland, started the first comprehensive model of a national economy.

During the same period, Wassily Leontief was formulating input-output analysis, first published in a 1936 article.(118) Leontief offered an operational version of Walras' general equilibrium analysis. With the help of a few heroic assumptions,(119) input-output analysis attempts to chart the flows of physical products from one sector of the economy to the next. It recognizes that, in addition to final consumption, many outputs from industry become inputs for other industries. The analysis charts the perturbations through the system of a planning decision or another exogenous change, noting especially the location of potential

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(118) Wassily Leontief, "Quantitative Input and Output Relations in the Economic System of the United States," 18 Rev. Econ. Stat. 39 (1936).

(119) The original assumptions included linear production functions, fixed coefficients of production, and the simplification of the economy into a relatively few sectors (46 in the 1936 article). For a biography of Leontief, see Leonard Silk, The Economists 1976, pp. 151-187.

bottlenecks.

The federal government first used Leontief's system in 1944 to help with war production planning. In the years following the war, government, industry, and academic economists all worked to refine econometric and input-output analysis.(120) Several factors contributed to the growth of these inductive models: the advances in information technologies described above;(121) the development of national accounting techniques by Kuznets and others; the explicit quest for full employment, and thus the need for macroeconomic planning by the federal government; and the increased need of large corporations, in an increasingly interconnected economy, for reliable planning tools.(122) For a time, the models achieved considerable success; for example, they predicted with great accuracy the effects of the 1964-65 tax cuts.(123) In recent years, however-- particulary since the 1973 oil price hikes, stagflation, and the resultant shift of many parameters beyond the range of historical experience(124) --the models have worked less well.

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(120) The latter can be considered a subtype, albeit an important one, of the former. Both terms describe the extensive use of quantitative data within a mathematical framework.

(121) Supra, Chap. II, sec. 4.

(122) Concerning the last point, see J.K. Galbraith, The New Industrial State, 1967.

(123) For a discussion of the success of the University of Michigan model at this time, see Finklestein and Thimm, pp. 331-332.

The ability of even the gigantic models of today(125) to handle the complexity of the modern American economy remains in question.

7. The History of Economic Thought and the Model of Increasing Complexity. This chapter has traced the somewhat complex yet essentially continuous progress of the model of increasing complexity in economic thought. The basically deductive models of the classicists and neoclassicists joined with the inductive work of the historicists and institutionalists to create the inductive models of econometrics.

The cybernetic models of econometrics,(126) and the Keynsian models which they have often detailed, remain the standard tools of most economists, although they have showed signs of stress in the late seventies. On the more ecological side, economists such as Kenneth Boulding have advocated the acceptance of biologically-based general systems theory over what they perceive as the overly-quantitative current models.(127) On the libertarian side, Milton Friedman and

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(124) E.g., at the time of this writing in spring of 1980, the prime interest rate is over 19%.

(125) Basman discovered 452 structural coefficients in the 1972 Brookings Model, in Karl Brunner, ed., Problems and Issues in Current Econometric Practice 1972, p. 5.

(126) Leontief describes the economic system cybernetically, "as a gigantic computing machine, tirelessly grinding out solutions to an unending stream of quantitative problems." Quoted in Silk, pp. 160-161.

the Chicago School(128) attack the inductive models from a laissez-faire perspective newly fortified with statistical data.

Such disagreements might seem to cloud the clear line of progress through the three-stage model. On the contrary, given the ineluctable role of values in economics,(129) disagreements on policy will always exist. More pertinent to the model, however, are the immense similarities among the views of Leontief, Boulding, and Friedman. All conform to the model in their acceptance of the need for empirical support for their propositions. All perceive a complex, interdependent, dynamic system. While their agreement certainly does not extend to a full acceptance of the inductive model world-view as described in the first chapter, their disagreements should not hide their substantial agreement with important parts of it. The growth of the American economy has fundamentally changed many of the relationships--economic, social, or otherwise--among members of society. No economist can ignore the growth of complexity without risk-

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(127) For a biography of Boulding, see Silk, pp. 191-239. Also, see Kenneth Boulding, Beyond Economics, 1968, Part II:General Systems and Society.

(128) For a biography of Friedman, see Silk, pp. 47-95. Also, see Milton Friedman, A Monetary History of the United States 1963.

(129) On this controversial point, see the discussion of arguments across paradigms in T.S. Kuhn, The Structure of Scientific Revolutions 2nd ed., 1970, pp. 198-207.

ing absurdity.

Chapter IV

LEGAL THOUGHT AND THE MODEL

1. The Study of Law. With the help of the thousands of legal decisions written each year, the legal historian confronts a much richer and more detailed body of material than does the historian of information technologies or economics. Yet this very wealth causes certain difficulties. The syntheses of great theorists cannot gloss over inconsistencies of value and doctrine: juries find for the "wrong" side; jurisdictions differ on great and small points; and the different fields of law-- contracts, torts, criminal or whatever-- as well as their subfields, convert to new doctrines at an uneven pace. The passive nature of law adds to the confusion. Because courts are constrained to rule on the case in front of them, the happenstance of a particular set of facts, of an idiosyncratic judge, or of a remarkably good or bad presentation by a lawyer can often create a precedent out of line with the general trend.

In approaching the jumbled mass of thousands of cases, this chapter will sketch how well many areas of law indeed fit the model of increasing complexity. In doing so, it will concentrate on two areas of law-- torts and administrative law. Tort law, defined broadly as concerning non-con-

tractual civil wrongs,(130) includes, among several other things, negligence, products liability, and nuisance. As defined by the leading authority on the field, William Prosser, each of these fields largely hinges on the concept of reasonabless-- reasonable risk of harm in negligence,(131) reasonable inspection and use of goods in product liability,(132) and reasonable justification for creating a nuisance that affects neighbors or the environment.(133)

Since 1850, however, the definition of "reasonable" has changed as the modal type of reasoning moved through the stages of increasing complexity. The laissez-faire belief in contracts between autonomous individuals dominated the "scientific" stage, which lasted until about 1910. The so-called "realists" then attacked the deductive doctrines of the scientific legalists, and attempted to replace them with the inductivism of sociological jurisprudence-- a new emphasis on the actual workings of justice, and not its abstract doctrines. In the third stage, tort law moved toward what Owen Fiss calls the "structural suit,"(134) in which judges

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(130) For a discussion of the intricacies of the definition of torts, see the acknowledged authority in the field, William Prosser, Law of Torts, 4th ed., 1971, pp. 1-4.

(131) Ibid., p. 146.

(132) Ibid., p. 667.

(133) Ibid., p. 575.

(134) Owen M. Fiss, "The Supreme Court 1978 Term; Foreward: The Forms of Justice," 93 Harv. L. Rev. 1, 1979.

often impose their own interpretation of constitutional goals onto a complex case involving many parties. In the course of this history, the volume of tort cases expanded tremendously (Prosser says in "geometric progression"),(135) one sign of the increasing importance of law as it mediated the spillovers of actions in our increasingly interconnected society.

While the primarily judge-made law of torts was growing along these lines, legislature-made administrative law also grew rapidly. Although federal regulation of industry dates back at least to the Steamboat Act of 1852,(136) the late nineteenth century witnessed the almost unchallenged sway of the laissez-faire market. The institutionalist challenge to the sanctity of the free market led to new institutions designed to correct market imperfections, e.g., the Interstate Commerce Commission in 1887 and the Food and Drug Administration in 1906. With the coming of the New Deal, the agencies began the planning typical of the use of inductive models, e.g., the interstate highway system, urban planning, and federal education programs.

2. The Transformation of American Law: The Triumph of Laissez-Faire. Morton Horwitz, in The Transformation of American Law, 1780-1860, (1977) describes the change away

(135) Prosser, p. xi.

(136) John G. Burke "Introduction to Symposium on Law and Technology," 45 S. Cal. L. Rev. vii, 1972.

from a common law based on Blackstone's maxim sic utere tuo, ut alienum non laedas (use your own property so as not to harm others) toward a new law of laissez-faire. Horwitz writes:

> By the middle of the nineteenth century the legal system had been reshaped to the advantage of men of commerce and industry at the expense of farmers, workers, consumers, and other less powerful groups within the society... The rise of legal formalism can be fully correlated with the attainment of these substantive changes.(137)

Horwitz convincingly documents a two-part process. First, the industrial and commercial interests broke down the old common law in order to establish markets free of traditional restraints. Then, beginning around 1850, they clothed their laissez-faire doctrines in the dignified robes of scientific law, as revealed in the texts of the leading appellate cases.(138) Law in the latter period followed, in general, what Fiss calls the "dispute-resolution" model,(139) and what Abram Chayes calls "private law litigation."(140) The two terms are substantially the same; this paper will follow Fiss' usage.(141)

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(137) Horwitz, pp. 253-254.

(138) Horwitz discusses scientific law, pp. 217219. G. Edward White discusses the importance of the deductive "case method" in Tort Law in America: An Intellectual History, pp. 44-55. Read in manuscript; published in spring, 1980. All citations to a manuscript text of 416 pages. Cited here as White.

(139) Fiss, p. 18.

(140) Abram Chayes, "The Role of the Judge in Public Law Litigation," 89 Harv. L. Rev. 1281, 1976.

The case Wheatley v. Baugh(142) illustrates the dispute-resolution model, as well as its strong bias in favor of the defendant's right to untrammeled use of his property. Baugh, a tanner, had won damages in a lower court from Wheatley, an agent of the Morris Mining Company. Morris Mining had twice started a large water pump in the copper mine adjacent to Baugh's tannery, and both times a spring required by Baugh for tanning had dried up, harming his business. Neither side contested the connection between the pumping and the drying-up of the spring. While acknowledging the old line of cases under sic utere, etc. protecting riparian landowners, the appellate court cited the principle cujus est solum ejus est usque ad coelum et ad infernos" (he who owns the soil has it even to the sky and to the lowest depths) and ruled for no damages.

In the dispute-resolution model, as exemplified by Wheatley,(143) one plaintiff ordinarily sues one defendant in order to remedy a particular, self-contained episode. The judge acts as a neutral referee, and the parties initiate

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(141) Fiss, pp. 35-36, correctly points to the public nature of all law, and thus the lack of clarity in Chayes' contrast between "private law litigation" and the later "public law litigation."

(142) 1 Casey Pa. 528 (1855).

(143) For a more extensive coverage of the relevant cases than space permits here, see Horwitz, Chapter 2, and Sidney Fine, Laissez-Faire and the General-Welfare State, A Study of Conflict in American Thought, 1865-1901 (1956), Chapter V.

and control the process. In terms of the model of increasing complexity, a judge deduces the correct decision for a particular case from a few general principles. The case involves autonomous individuals arguing about a discrete occurrence in the past. Without allowing for the claims of society in general or of any potential third party, the judge awards the disputed sum to the rightful owner, rightful in the sense that the property belongs to the individual as a natural part of his person.

Wheatley shows a deductive-stage approach to available information. When ruling in the case, the court said: "But percolations spread in every direction through the earth, and it is impossible to avoid disturbing them without relinquishing the necessary enjoyment of the land."(144) A rule forbidding a man to disrupt such percolations "would amount to the total abrogation of property."(145) There the matter rested; no one talked of bringing in expert witnesses to ascertain the degree of cause. And the court went even further. It concluded that the hidden veins of water "are not apparent, and the owner of the land is not bound to resort to an action to redress a wrong of which he cannot by any possibility have notice."(146) Yet such a standard of "any possibility" was farcical given the clear evidence,

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(144) Wheatley, at 532.

(145) Ibid., at 532.

(146) Ibid., at 534.

acknowledged by defendant, that the water-pumping had damaged the plaintiff. The court, in effect, gave permission to enterprises to ignore easily obtained information about the harm they caused, while justifying its decision on the grounds that the enterprises did not have the relevant information.

Wheatley indicates the mid- and late-nineteenth century conception of property. Based on the principle of sic utere, etc., earlier common law had declared many industrial projects nuisances, or else had held the industrialist strictly liable for any damages caused by his enterprise. After about 1850, however, the principle of negligence increasingly replaced the earlier, more anti-industrial, doctrines.(147) With its permission to the defendant to act with "reasonable risk of harm,"(148) the negligence principle greatly extended the ability of property-owners to injure their neighbors without penalty. During the second half of the century, scientific legalists "discovered" from their examination of important appellate cases a dense thicket of negligence-related doctrines which sheltered the property of the autonomous businessman: proximate cause, contributory negligence, assumption of risk, fault, the fellow-servant rule, the public nuisance doctrine, and the doctrine of wrongful death.(149) As Lawrence Friedman writes,

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(147) For a brief description of what constitutes negligence, see Prosser, pp. 143-144.

(148) Ibid., p. 1146.

"[By 1890] the thrust of the rules, taken as as whole, approached the position that corporate enterprise would be flatly immune from actions sounding in tort."(150)

3. Realism in Muller v. Oregon. In an 1892 speech, the prominent New York lawyer William Guthrie said: "Today more than ever, the bar is the great conservative force in America."(151) By that year, as discussed in previous chapters, both information technologies and economics had entered the inductive stage,(152) yet law stayed firmly stuck in deductive scientism for another fifteen years. Alpheus Mason writes:

> The lawyers' failure to keep up with social and economic progress... was as old as the profession itself-- it was inherent in the very process of erecting a working law for today upon the precedents of yesterday and the day before.(153)

As the century drew to a close, the bench maintained its aloofness from social realities in the face of increasing public protest. In order to check the humanitarian impulses of the state legislatures, "judicial review reached its most

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(149) See White, pp. 61-84. Also, see Lawrence Friedman A History of American Law (1973), pp. 412-24419.

(150) Friedman, p. 417. He adds: "Of course, courts never went so far, and never wanted to. They did not want to encourage carelessness [by business], and they were never entirely without heart."

(151) Fine, p. 139.

(152) Supra, Chap. II, sec. 1; Chap. III, sec. 3.

(153) Alpheus T. Mason paraphrasing Brandeis in Brandeis: A Free Man's Life (1946), p. 246.

bizarre excesses."(154) Lawrence Friedman catalogues a long list of anti-laissez faire legislation, primarily at the state level, which was enacted between 1870 and 1900: The Grange laws, railroad rate regulation, insurance commissions, and many others.(155) However, courts struck down down many of these interventionist laws, largely on the basis of an extremely broad reading of the due process clause of the Fourteenth Amendment. In one particularly fervent outburst, Judge Andrews of the New York Court of Appeals ruled that the legislature had no power "to regulate private business, prescribe the conditions under which it shall be conducted, fix the price of commodities or services, or interfere with the freedom of contract."(156) The support of the Supreme Court for the due process clause reached its peak in Lochner v. New York (1905),(157) in which the Court rejected a New York law limiting the bakers' work week to sixty hours, as contrary to the due process clause and to freedom of contract.

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(154) Friedman, p. 298. For a history of judicial review during the period, see Fine, pp. 126-166.

(155) Friedman, pp. 384-408.

(156) People v. Budd, 117 N.Y. 1, 69 (1889). Quoted in Fine, p. 135. Fine explicitly likens Andrews' attitudes to those of "the bulk of his colleagues," p. 132.

(157) 198 U.S. 45 (1905).

Finally, in 1908, Louis D. Brandeis, prior to his appointment to the Supreme Court, won an overdue restriction of the due process clause in Muller v. Oregon(158) --what one might well call the first case of the inductive stage. In that case, the Court, only three years after Lochner, upheld the constitutionality of an Oregon statute limiting women in laundries to ten hours work per day. In addition to the usual legal-deductive arguments based on previous cases, Brandeis took the revolutionary step of adding over one hundred pages of sociological evidence to his legal brief. As one observer noted:

> The distinguishing mark of Mr. Brandeis' argument was his complete mastery of the details of the subject and the marshalling of the evidence. Slowly, deliberately, without seeming to refer to a note, he built up his case from the particular to the general, describing conditions authoritatively reported, turning the pages of history, country by country, state by state, weaving in with artistic skill the human facts--all to prove the evils of long hours and the benefits that accrued when these were abolished by law.(159)

The Court, in paying the unusual compliment of naming Brandeis in the decision,(160) ruled:

> As healthy mothers are essential to vigorous offspring, the physical well-being of woman is an object of special interest. The regulation of her hours of labor falls within the police power of the State, and a statute directed exclusively to such regulation does not conflict with the due process or equal protection clauses of the

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(158) 208 U.S. 412 (1908).

(159) Josephine Goldmark, quoted in Mason, p. 250.

(160) Muller, at 419.

Fourteenth Amendment.

> The right of the State to regulate the working hours of women rests on the police power and the right to preserve the health of the women of the State, and is not affected by other law of the State granting or denying to women the same rights as to contract and the elective franchise as are enjoyed by men.(161)

Here we see many characteristics of the inductive stage clearly stated by the courts for the first time. Muller marks the beginning of the realist school, distinguished by its inductive method, such as what Brandeis used when he "built up his case from the particular to the general." Instead of endless mulling on past cases, Muller encouraged "presentism": "a tendency to assess intellectual contributions in terms of their contemporary relevance and applicability."(162) Along with the institutional economists, realists understood the need for cross-disciplinary study of the complex society of the day; Brandeis remarked: "a lawyer who has not studied economics and sociology is very apt to become a public enemy."(163) Together with the related school of sociological jurisprudence,(164) realism

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(161) Muller, at 412.

(162) White, p. 116.

(163) Quoted in Mason, p. 246.

(164) In "From Sociological Jurisprudence to Realism," 58 Va. L. Rev. 999, especially at 1020, White distinguishes between the two schools, linking the sociological jurisprudence of Roscoe Pound and Brandeis with the Progressives, and the realism of Karl Llewelyn and others with the New Deal. In the context of the model of increasing complexity, however, the schools did not differ importantly. Their chief disagreement con-

encouraged the examination of how law actually worked, and not merely of the doctrines with which courts justified their decisions; Brandeis wanted "not to displace the courts, but to make them efficient instruments of justice."(165)

As seen in Muller, the world-view of the realists conformed very well to the inductive-stage perception of a number line. The decision accepted a population-- the women of Oregon-- as the correct unit of analysis. As Brandeis' brief showed, unregulated freedom of contract had led to an externality(166) : individual contracts with the employer for long hours caused a high proportion of unhealthy mothers, in conflict with the public interest. Empirical data thus formed the basis for regulation of this market imperfection, and an individual woman's right to contract for injuriously long hours was thus subordinated to the best interests of all the women in Oregon, and of society in general.(167)

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cerned Pound's clinging to a faith in natural law; for this reason, the realists can be seen as better representing the inductive stage, while the sociological jurisprudes appear a transitional phase.

(165) Mason, p. 246.

(166) As in the previous chapter, for ease of exposition current terms will be used to explain the concepts of earlier writers.

(167) See Appendix for a discussion of the pervasiveness, in our increasingly interdependent society, of this tradeoff between freedom and the general welfare.

4. The Age of Realism in Administrative and Tort Law. Muller cleared the way for the string of social legislation leading to the New Deal, but laissez-faire law did not become extinct immediately. Many regulations went through fitful progress. For example, New York's 1910 workmen's compensation law was declared unconstitutional,(168) but Wisconsin's bill the next year passed judicial review, and by 1917 forty states and territories had workmen's compensation.(169) During the same period, LaFollette's Progressive policies became law in Wisconsin,(170) but Arizona's attempt at an old-age pension failed judicial review in 1916.(171) In short, Muller heralded a long transitional stage in administrative law that persisted through Franklin Roosevelt's battle with the Supreme Court over the N.R.A. in the 1930s.

During this time, government agencies added bulk to their once-scrawny frames. States regulated public utilities, restricted child labor, and began after 1912 to pass mimimum wage laws for certain occupations. The federal government tightened control of banking, passed the Clayton Anti-Trust Act, and increased the power of the ICC to regulate rail-

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(168) Ives v. South Buffalo Railway Co., 201 N.Y. 271, 94 N.E. 431 (1911). Cited in Friedman, p. 587.

(169) Fine, p. 385.

(170) Supra, Chap. III, sec. 5.

(171) Fine, p. 385.

roads.(172) These laws, in the main, conformed to the second-stage correction of imperfections in market mechanisms; systemic, purposive planning awaited the inductive models which emerged from World War II.

Between 1910 and 1940, the years White gives for the realist period, the law of torts experienced important doctrinal changes, particularly in the definition of negligence. The doctrine of last clear chance modified the old doctrine of contributory negligence by saying that the plaintiff's contribution to the eventual injury did not free the defendant from liability if the defendant had the last clear chance to prevent the injury. Despite the weakness of its doctrinal roots,(173) last clear chance became acceptable after 1900, as a way to aid the plaintiff in negligence cases. Another doctrine which revealed the new bias toward correcting the perceived imbalance in favor of defendant was res ipsa loquitur (the thing speaks for itself).(174) The doctrine allowed, in many cases, "plaintiffs injured by defective products to create a rebuttable presumption that their injuries had been caused by negligence merely by describing the circumstances of the injury."(175) The use of the doctrine in the United States dates back to 1868,(176)

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(172) For an overview of the period, see Fine, pp. 383-400.

(173) See Prosser, pp. 427-429.

(174) Discussed in Prosser, pp. 211-228.

(175) White, p. 304.

but Prosser cites almost no cases before 1900, and "it was the middle 20th century, so eager for theories of corporate liability, that really made the doctrine its own."(177)

The two doctrines of last clear chance and res ipsa loquitur gave judges alternatives to the earlier limitations on liability, and helped release them from the strict doctrines of the past. Judges in the realist period could choose the new doctrines and then use contemporary policy goals as further grounds for their decisions. The new definition of causation provided the theoretical basis for that increased role of policy in judicial decision-making.

Leon Green, prominent realist and teacher of William Prosser, believed that earlier writers on causation had confused two distinct stages in the determination of liability.(178) The first stage Green called "causal" or "factually causal" in the traditional "but-for" sense: "One fact or event is a cause of another when the first fact or event is indispensable to the existence of the second."(179) This idea of cause

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(176) Friedman, p. 419, cites Illinois Central Rr. v. Phillips 49 Ill. 234 (1868).

(177) Ibid., p. 419.

(178) This discussion of Green and causation follows his 1927 book Rationale of Proximate Cause as described in White, pp. 155-160.

(179) Wex S. Malone "Ruminations on Cause-in-Fact," 9 Stan. L. Rev. 60. Malone goes on to show the need for a broader definition of factual cause than allowed for in the "but-for" sense.

led to Prosser's famous dictum: "Causation is a fact. It is a matter of what in fact has occurred."(180) As a question of fact, causation is a matter for the jury to decide. However, in Green's theory, the finding that the defendant caused the damage is merely a necessary but not a sufficient condition for the award of damages.

Green labeled the crucial second part of his analysis of causation "legal" or "proximate" cause. Given a finding of causation by the jury, the judge must next decide whether the defendant proximately caused the damage, that is, whether the defendant owed a duty to the plaintiff to prevent the damage. Greeen attacked the scientists' concept of a "negative duty of very great generality owed by all the world to all the world"(181) ; in its place, he proposed an empirically-based determination of duty derived from the actual relation between the particular plaintiff and defendant.

The terms "relation" and "risk" tied together Green's analysis of causation. Using the interest-group theory of politics then current,(182) Green's theory asked each judge,

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(180) Prosser, p. 246.

(181) White quoting Oliver Wendell Holmes, p. 157.

(182) White, p. 158. The interest-group theory of politics focused on the institutional position of actors in the political system. Elsewhere, White notes the strong similarities between realist law and other social science disciplines of the time such as "instrumentalist" economics, "pragmatist" philosophy, "behaviorist" psy-

once the jury had established the fact of causation, to follow three steps: (a) define the relational interests at stake in the given case; (b) evaluate whether the action at issue constituted an unreasonable risk given the interests of society in the competing institutions, and (c) decide compensation. Green's casebook for torts(183) illustrates his theory of causation. Whereas earlier casebooks had explained cases in terms of the doctrines which they exemplified, Green's book attempted to show that torts concerned "persons [who] have interests which are subjected to harms against which the judicial process gives protection."(184) In the index, a search for cases on contributory negligence, for example, would have found references to "automobile traffic," "manufacturers and dealers," and other "functional" categories.(185)

In terms of the model of increasing complexity, Green's realism(186) conforms quite well to the inductive-stage perception of a population grouped around a mean. Risk is a

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chology and sociology, and "progressive" history. White, p. 119.

(183) The Judicial Process for Tort Cases (1931).

(184) Green, The Judicial Process in Tort Law p. iv, quoted in White, p. 146.

(185) White, p. 146.

(186) White warns that assorted realists differed somewhat in their attacks on the scientists' doctrines. Green is important because of the internal coherence of his system and because his training of Prosser greatly affected post-war tort theory.

"measure of the probability and severity of adverse effects" and depends in its definition for some population against which to measure probability.(187) Relation, in Green's usage, refers to the specific institutional interests at stake in a case. Since, in the interconnected world of the institutionalists, society at large has some of those interests, judges must form policy to correct for public interests, e.g., the health of working mothers or the protection of consumers from unsafe products. In the realist view, slavish reliance on doctrinal deduction from past cases leads to the belittling of the true goal--the actual administration of justice in society's interest.

In the realist period, nonetheless, doctrines such as last clear chance and res ipsa loquitur did play an important role, for two main reasons. First, the victory of the realists took place within an often conservative legal community which, even after much of it accepted the realist proposals, felt compelled to legitimize changes in the language of the traditional doctrinal form. Second, as in economics,(188) supporters of the inductive view never won complete victory. Neoconceptualists such as Francis Bohlen remained prominent during the twenties and thirties, and realists could somewhat blunt the counterattacks of such neoconceptualists by phrasing their decisions in the form of

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(187) William Lowrance Of Acceptable Risk (1976).

(188) Supra, Chap. III, sec. 4.

doctrines.(189)

5. Administrative Law in the Planning Era. The Second New Deal and World War II left a legacy of active government planning unmatched by previous experience.(190) After the war, such planning continued and expanded. Bureaucracies moved beyond the mere correction of market imperfections into the planning of whole systems. The inductive-stage regulation usually required only (a) a determination of the degree of the imperfection (for instance, of the amount of ill health caused by long working hours) and, (b) a policy determination of the extent of regulation (whether to allow a ten-hour or an eight-hour day). The regulation ordinarily corrected along a single dimension (the proper length of the work day).

In order to control the huge and complex systems of the third stage, the agencies needed to expand their methods greatly. Successful urban renewal, for example, must effectively coordinate, among many other things, the interrelated areas of tax policy, housing policy, and transportation policy.(191) Such coordination requires expertise in the

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(189) White, pp. 142-146.

(190) In contrast, Joseph Dorfman, The Economic Mind in American Civilization 1946-1959, Vol III, pp. 477-485 describes the very swift dismantling after 1918 of the World War I planning boards.

(191) For an examination of the role of inductive models in urban plannin, see Martin Greenberger, Matthew A. Crenson, and Brian L. Crissy, Models in the Policy

process of coordination-- the gathering of useful statistical data within an analytic framework. In other words, the planning of complex systems by government agencies required inductive models, as made manifest by the administrative law overseen by the agencies.

6. Tort Law, the Structural Suit, and Reserve Mining. As discussed above in section 4, the inductive-stage realists dominated tort law before World War II with their emphasis on restricting doctrine and their encouragement of empirical examination of the actual workings of the administration of justice. Their antipathy to the concept of universal laws, and their acceptance of the interest-group theory of politics led to a belief in the pervasive presence of policy aspects of legal cases.

The grounds for making those policy decisions remained unclear. The facts of cases did not always speak for themselves, and such reliance on induction could lead to open conflict between judges with different perceptions of the facts, i.e., with different values. Critics accused the realists of moral relativism, and some of the accused accepted the charge.(192) However, with the coming of World War II and the perceived need for national unity and shared values, relativism became insupportable.(193) In its place

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Process 1976.

(192) White, pp. 257-258.

arose what White calls "the new consensus" in tort law, led by William Prosser. As White describes the new consensus:

> A seemingly insoluble tension in law between abstract general guidelines amd indeterminate particular decisions was alleviated by careful analysis of the processes by which decisions were made and justified. The dilemmas of Realism were 'solved' by a combination of improved professional techniques and renewed attention to the common bonds of American civilization.(194)

Fiss describes this new emphasis on process with his term "the structural suit" (in contrast to the dispute-resolution model described above in section 2) while Chayes talks of "public law litigation" replacing "private law litigation."

Reserve Mining v. United States(195) illustrates how the neat packages of earlier disputes have unravelled into the tangled controversies of our modern industrial culture. Space limitations prevent a full account of the ten-year long case,(196) but even an abbreviated account can

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(193) Ibid., p. 258.

(194) White, p. 264. Emphasis added.

(195) Actually a long string of cases: 380 F.Supp. 11 (consolidation of 3 decisions) 6 ERC 1448, 6 ERC 1657, 6 ERC 1919 (D. Minn. 1974); injunction stayed 498 F.2d 1073, 6 ERC 1609 (8th Cir. 1974); remanded sub nom. 514 F.2d 492 (consolidation of two opinions) 7 ERC 1618, 7 ERC 1782 (8th Cir. 1975), request to vacate stay denied 419 U.S. 802, 7 ERC 1113 (1974); 420 U.S. 1000 (1975).

(196) In addition to the bulky court decisions, see: Marcia R. Gelpe and A. Dan Tarlock, "The Uses of Scientific Information in Environmental Decision-Making," 48 S. Cal. L. Rev. 371, 1974; "Note: Reserve Mining-- The Standard of Proof Required to Enjoin an Environmental Hazard to the Public Health," 59 Minn. L. Rev. 893, 1975; and David Zwick and Marcy Benstock, Water Waste-

demonstrate how the interrelated aspects of form, substance, and function all had developed considerably from the dispute-resolution model used in Wheatley.

Reserve Mining Company opened a taconite (low grade iron ore) "beneficiating" plant on the shores of Lake Superior in 1955. The plant began operations at its present level in 1960. In 1969 the Minnesota Environmental Protection Agency began action against Reserve Mining for violations of state pollution statutes. At that time the plant was dumping 67,000 tons of taconite tailings into the lake each day. Controversy in the case centered on the effect that the tailings, which during the course of the litigation proved to include low levels of asbestos fibers, were having on the public water supplies of Duluth and other nearby cities. Air emissions from the plant also included these fibers. After interminable litigation, resolved finally on the tort law of public nuisance, the plant finally stopped the dumping in March, 1980.(197)

The form of the case follows from the recognition today of the interdependence of society. As Chayes describes the modern case:

> The party structure is sprawling and amorphous, subject to change over the course of the litigation. The traditional adversary relationship is suffused and intermixed with negotiating and

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land 1971, pp. 140-166.

(197) New York Times March 18, 1980, p. A16.

> mediating processes at every point. The judge is the dominant figure in organizing and guiding the case, and he draws for support not only on the parties and their counsel, but also on a wide variety of outsiders-- masters, experts, and oversight personnel.(198)

In the place of the two individuals involved in Wheatley, Reserve Mining had eleven plaintiffs and ten defendants, many of them groups with hazily-defined membership.(199) The rise of the class action suit, though not evident in Reserve Mining, is another indication of the move away from cases between autonomous individuals.(200) The long legal history corroborates Chayes' other points about the complexity of the negotiating process and the use of expert witnesses.(201) All of these aspects of legal form match the increased fuzzing together of once-discrete structural units so characteristic of the network of the inductive modelling stage.

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(198) Chayes, p. 1284.

(199) Parties listed at 514 F.2d 492. Fiss describes the importance of the new nature of group membership, pp. 19-20.

(200) See, e.g.: "Note: Developments in the Law-- Class Actions," 89 Harv. L. Rev. 1319, 1976, and A. Peter Parsons and Kenneth W. Starr "Environmental Litigation and Defendant Class Actions: the Unrealized Viability of Rule 23," 4 Ecology L. Q. 881, 1975.

(201) See, e.g., "Note: Reserve Mining" for the active roles played by the several judges. 380 F.Supp. 14 cites the use of over 100 witnesses, many of them experts, in the case.

The substance of Reserve Mining dwarfs the simple problems discussed in Wheatley. We saw in the earlier case that the court specifically exempted a company from liability when the source of the harm was "not apparent," even when the clear relation between the pumping and the spring's stoppage indeed made the source apparent. In Reserve Mining the causal link between the tailings and a public health hazard was far less apparent. Even 1621 exhibits and 18,000 pages of transcript did not conclusively demonstrate the link.(202) However, sophisticated scientific experiments and testimony by world experts eventually convinced the courts to end the dumping.(203) In paying attention to experimental data presented within the abstract mathematical framework of, for instance, a hydrodynamic model of tailing drift in Lake Superior, the courts showed an acceptance of highly advanced information technologies.(204) The courts also

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(202) The statistics are quoted at 380 F. Supp. 14. The problem of cause was the major point of conflict between the ruling of the district court, 380 F. Supp. 14, and the first ruling of the court of appeals, 498 F.2d 492.

(203) Little study has been done of the history of expert witnesses. According to Cathy Leeco and James Beniger, researchers in the field, courts allowed only very limited use of experts until the late nineteenth century. The use of experts gained considerably broader legal recognition after English v. State 85 Texas Crim. 450, 213 S.W.2d 632 (1919) and Frye v. United States 293 Fed. 1013 (D.C. Cir. 1923), near the start of the empirically-based realist period. By the time of Reserve Mining, the use of experts was widespread.

(204) 498 F.2d 516. The decision several times also refers to the inherent uncertainties in scientific investiga-

showed an inductive modelling appreciation of the intricacies of factual causation in their willingness to accept the multivariate causation typical of environmental cases.(205)

The case Burr v. Adam Eidemiller, Inc.(206) shows how acceptance of expert scientific testimony dramatically changed the substance of the law. The facts paralleled Wheatley almost exactly: three days after a road construction company began dumping onto a slag pile, the spring on the plaintiff's land became polluted, killing the fish in the plaintiff's pond and wrecking his plumbing system. In Burr, however, a chemist did a dye test tracing the contamination from the slag pile to the plaintiff's spring. Whereas the court in Wheatley could call the source of the harm "not apparent" and say the defendant did not have "any possibility" of foreseeing the harm, the court in Burr, convinced by strong scientific testimony, awarded the plaintiff $16,000 damages.(207)

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tion, another characteristic of inductive models but not of the earlier stages; e.g., at 517 and 518.

(205) For discussions of inductive-model ideas of causation see: D. Lerner, ed., Cause and Effect 1965; Gelpe and Tarlock; and Louis L Jaffe and Laurence H. Tribe Environmental Protection 1971. For standards of review in admimistrative cases, see Harold Leventhal, "Environmental Decision-Making and the Role of the Courts," 122 U. Pa. L. Rev. 509, 91974.

(206) 126 A.2d 403 (11956).

(207) The court cited the defendant for "intentional misconduct" in light of the company's clear knowledge of the source of the harm; Burr, at 404.

Burr points out that the structural suit did not entirely replace dispute resolution in recent law.(208) The rise of the structural suit did, however, change the main function of tort law. In contrast to the backword-looking scientific law, or the presentism of the realists, the law of structural suits became future-oriented. In Reserve Mining, the damage from asbestos would not occur for at least thirty years after exposure; yet, the courts brushed aside the old doctrine of imminent irreparable injury in order to prevent injury that did not at all fit the traditional definition of imminent.(209) Instead of blaming a person for his negligent action in the past, courts now tried to develop processes and structures which would lessen the probability of harm in the future.

To give one example, between World War II and 1970 courts adopted strict liability rules for product safety, which replaced the defendant-oriented negligence doctrines of the laissez-faire period and the case-by-case res ipsa loquitur of the realist period.(210) The purpose of strict liability was to deter future wrongdoers rather than punish exactly

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(208) Because the road construction ended before the trial, Burr actually conforms in every way except verdict with the earlier model.

(209) See Charles L. Hellerich, "Note: Imminent Irreparable Injury: A Need for Reform," 45 S. Cal. L. Rev. 1025, 1972.

(210) White, pp. 298-304. See generally, Dix W. Noel and Jerry J. Philips, Products Liability in a Nutshell 1974.

those who had committed wrongdoings in the past. Such a future-orientation meshed well with the inductive modelling concepts of efficiency and operationalization: "the 'injustice' of the common law was muted by its ease of administration."(211)

Another way to describe the future-oriented function of the structural suit is to recognize its planning function. Fiss uses the string of school desegregation and busing cases which followed Brown v. Board of Education to make his point about modern judges' new role as planners of complex systems.(212) Talking about the "decidedly bureaucratic" reality of the desegregation efforts, Fiss describes the operational difficulties, and eventual triumphs, of the pursuit of the goal of racial equality. In such systems, the urgency of the goal prevents the remedying of most individual incidents of discriminations (first-stage problems). It often also prevents the correction of particular types of discrimination at any given time (second-stage problems), because overall strategy might dictate that other sectors change first. In the structural suit, all decisions should be made from a third-stage understanding of how to reach the ultimate goal. The structural suit, triumphant in the

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(211) White, p. 298. For a discussion of efficiency in law, see Robert C. Ellickson, "Alternatives to Zoning: Covenants, Nuisance Rules, and Fines as Land Use Controls," 40 U. Chic. L. Rev. 681, 1973.

(212) Brown v. Board of Education 347 U.S. 483 (1954). Fiss, pp. 2-5.

linked aspects of form, substance, and function, shows the pervasiveness of future-oriented inductive models even in the tradition-bound field of law.

Chapter V

CONCLUSION: SOME LESSONS FROM HISTORY

1. The Model: A Review of Three Stages. The last three chapters have traced the similarities among the histories of information technologies, economics, and American law. The deductive stage was oriented toward the past-- toward the deductive working-out of the unchanging universal laws typical of laissez-faire. The use of formal logic in this first stage conformed to perceptions of discrete units of analysis, such as autonomous individuals, and the string-of-beads number line, and contained practically no allowance for the spillover effects of individual action.

In the inductive stage, statisticians, institutionalist economists, and realist lawyers all tried to bring the older stage to its senses. The inductivists emphasized the empirical examination of an interconnected society, as seen in terms of a population distributed around a mean. They realized the need to correct for the imperfections which often arose from application of the overly-abstract deductive theories. The statistical techniques of correlation, the new economic research bureaus, and the surveys of sociological jurisprudence all helped inductivists to assess situations more accurately. Causation moved beyond formal logic into

an estimation of fact based on statistical techniques. The development of the analysis of variance method late in the stage showed an awareness of the growing need for multivariate explanation.

After World War II came the wave of the future-- the inductive modelling stage. Rather than dawdling in the raw data of the present, cyberneticists, econometricians, and practitioners of the structural suit all included future-oriented planning in their approach to dynamic systems. Causation became multivariate and often uncertain, as complex feedback loops produced counterintuitive perturbations through the system. Matrices solved on the computer became the typical mathematical description of the complex networks. Once-autonomous individuals became diffused, for purposes of analysis, into operationalized bits of consumer preferences and class-action suits.

2. Some Lessons of History. An engineering student hurrying to solve his linear programming problem set might well not understand any reason to care about the history described in this thesis. Similarly, an economist worried about predicting this year's inflation rate from his econometric model has little time to dwell on the philosophical implications of his approach to economic analysis. Both of these initiates of inductive modelling live almost entirely within the third-stage world-view. They learn their trades

from ahistorical textbooks which propound the "correct" methods of analysis. They carefully master the most efficient algorithms for their current tasks, seldom questioning the appropriateness of those tasks.

Yet, these tasks of the information technologist, the economist, and the lawyer have changed radically in the last one hundred years. Though this conclusion might not surprise the historian, the degree of the change, when brought to their attention, often shocks both engineers and economists. This lack of historical perspective fits with the "radical" nature of inductive models in the strict sense of the word; inductive models go directly to the empirical "root" of the problem in order to find a solution in the most efficient way. Knowledge of outdated techniques does not seem to help solve the problem at hand.(214)

Lacking historical perspective, contemporary students of textbooks begin to believe in the unique appropriateness of the current techniques. They do not realize that people in each previous state have also believed that they had found the proper methods of analysis. Scientific deductivists

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(214) Because of the continuing power of precedent in legal decisions, the law has been spared the most virulent strains of ahistoricism. However as G. Edward White Tort Law in America: An Intellectual History (1980), pp. 366-400, there has been since the late sixties a vigorous expansion of legal theorizing divorced from the historical roots of the concept of justice. Calabresi, Fletcher, and Posner are prominent examples of such theorists.

swept away the cobwebs of mercantilist tradition in their quest for the universal laws embodied in laissez-faire. The inductive institutionalists and realists scorned the possibility of universal laws, but believed they had found the way, in North's words, to "modern, humanitarian, [and] scientific" laws though the application of statistical techniques.(215)

The first lesson of history-- that the world-views have changed considerably during the past century-- leads to the second lesson-- that there is no reason to expect the change to end with the inductive modelling stage. In order to generate the fervor which marked much of the debate between deductivists and inductivists, people on both sides must have believed quite firmly in the appropriateness of their philosophies. Only time and experience revealed the fatal flaws in the methods of the earlier stages. Extreme laissez-fairism became insupportable after 1900 when its deductively-formed recommendations for society clearly contradicted common-sense observations of the imperfections in unregulated market mechanisms. During the second stage, institutionalist economists and realist lawyers eventually realized, as White noted,(216) the need for a sturdy framework of analysis with which to grind their overflowing piles of empirical grist. Today, the third-state information

(215) Quoted supra, Chap. II, sec. 1.

(216) Supra, Chap. IV, sec. 6.

technologies-- operations research, cybernetics, and general systems theory--all have reached their thirtieth birthdays. It would be surprising indeed if evolution through the model of increasing complexity should suddenly stop now; rather, the history in this thesis should lead us to expect continued change in the future.

3. The Central Role of Information Technologies. As stated in Chapter I, the example of Darwinian evolution shows that progress from stage to stage does not necessarily imply a teleological progression toward the "correct" world-view. It may well be that laissez-faire described the early nineteenth century British economy of atomistic firms better than today's sophisticated econometric models describe our far more complex modern economy. The current failings of the econometric models, however, highlight even more poignantly the importance of information technologies to twentieth-century society. Even our sophisticated techniques cannot match the spiralling complexity of the problems.

As our world has become increasingly complex, information technologies have become the crucial tools for shaping and examining that complexity. Information technologies in the second and third stages have taught how to think about many aspects of American society. As M.G. Kendall said above about the period 1890-1910, statistics suffused all of life, and took as their objects for study everything from physical

objects, to human beings, to the weak endings of Shakespeare's verse.(216) In the seventy years since 1910, the use of quantitative descriptions of the world, as manifested today in inductive models, has cut across almost all disciplines, radically altering the form, substance, and function of each of them. By fundamentally changing the outlooks of lawyers, economists, and scientists, they have reshaped society.

In order to demonstrate the importance of the information technologies, this thesis has discussed the history of the common intellectual developments in information technologies, economics, and law. This history shows the central importance of information technologies to these parallel developments. Information technologies, as they have spread throughout diverse intellectual disciplines, have provided the necessary preconditions for progress in those disciplines. To take one example, econometrics could not have even approached its current sophistication without the many improvements in the processing of huge sets of data brought about by the information technologies.

Even the traditional, precedent-bound field of law has not been immune to the revolutionary impact of the shift in world-view inherent in information technologies. Whereas, in the nineteenth century, courts focused on relatively sim-

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(216) Supra Chap. II, sec. 1.

ple sets of facts in an effort to fit them into a standard deductive framework, the present legal system has had to resort to the use of information technologies to settle increasingly complex factual issues. Such factual issues, in turn, require the full powers of the modern structural suit for the management of their far-reaching implications.

Far beyond the mere effects of advances in calculating techniques, the ramifications of the new information technologies have changed the vocabulary and thought of America. Just as Kendall could describe the new pervasiveness of statistical thought at the turn of the century, so now the philosophy of the inductive model has become the accepted way of perceiving many problems. For one example, the word "feedback" has jumped from the abstruse realm of communications theory into the jargon of pop psychology. For another, think of how many people budget their time today in order to "optimize" their "output." No one could even have said such a sentence before the triumph of inductive models: the 1930 Oxford English Dictionary defined "optimize" simply as "to act as an optimist," while "output" was considered primarily as an obsolete Medieval inversion of "to put out of a house.(218)

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(218) Oxford English Dictionary, Vol VII, p. 160 for optimize, p. 260 for output.

4. Stage 4? For all the widespread effects of current information technologies, the model of increasing complexity will not suddenly stop evolving. Already the limitations of the inductive models are becoming increasingly apparent. Vast extensions of physical and information technologies have released man from many of the traditional tasks of society. Still left unsolved is the resolution of conflicting values. Such values become the objects of study in a new era, as techniques for balancing values such as cost/benefit analysis, technology assessment, and acceptable risk assessment(218) become the tools for analyzing many of society's most burning issues.

The history of the pesticide DDT offers an apt moral for the limitations of the third stage.(219) First used during World War II, the chemical proved spectacularly effective at controlling the pests which caused typhus, other diseases, and crop damage. After the 1962 publication of Rachel Carson's Silent Spring, the public became aware of the dangers of DDT: The chemical spread throughout the world, concentrated in the food chain, and threatened some species with extinction. In an entirely analagous way, advanced information technologies were initially received as a panacea for the complex ills of modern society. With the rise today in

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(218) See Appendix II for examples of the range of goals necessary for such assessments.

(219) For the history, see William Lowrance, Of Acceptable Risk, 1976, pp. 155-173.

the importance of values-- as the relentless operationalization forces lawyers, scientists, and economists to quantify the essentially unquantifiable-- the third-state inductive models begin to do more harm than good, subtly poisoning the essential and indescribable links that make a disparate community a society.

Appendix I

FORM, SUBSTANCE, AND FUNCTION OF THE THREE STAGES

I. DEDUCTIVE STAGE:
FORM: string-of-beads number line.
SUBSTANCE: 2 variables, one independent, one dependent.
deterministic causation.
FUNCTION: past-oriented (universal, unchanging laws)

II. INDUCTIVE STAGE:
FORM: continuous number line; distribution of a population around a mean.
SUBSTANCE: 2 or more variables.
statistical causation; correlation.
FUNCTION: present-oriented (description).

III. INDUCTIVE MODELLING STAGE:
FORM: interactive network.
SUBSTANCE: many variables, often measured in time-series.
complex, counter-intuitive operationalized causation.
FUNCTION: future-oriented (prediction).

Appendix II

THE COMPLEXITY OF DECISION-MAKING: THE MANY CRITERIA FOR VALUES DECISIONS

William Rowe in "Governmental Regulation of Societal Risks," 45 George Washington Law Review, pp. 959-960:

FACTORS IN RISK EVALUATION

I. Factors involving types of consequences.
   - A. Voluntary and involuntary risks.
     1. Equity and inequity in risk imposition.
     2. Risk agent's knowledge of risk imposition.
     3. Avoidability of risk and alternatives to risk.
     4. Exogenous and endogenous imposition of risk.
   - B. Discounting of latent risks.
   - C. Spatial distribution and discounting of risks.
   - D. Controllability of risk.
     1. Perceived degree of control.
     2. Systemic control of risk.

II. Factors involving the magnitude of probability that a consequence will occur.
   - A. Low probability levels and thresholds.
   - B. Spatial distribution of high probability risks.
   - C. Individual risk assessment and propensity for risk-taking.

III. Factors involving the nature of consequences.
   - A. Heirarchy of need fulfillment.
   - B. Common vs. catastrophic risks.
   - C. Special situations.
     1. Military vs. Peacetime.
     2. Life-saving functions.

This listing of the many factors necessary for risk evaluation shows how difficult the balancing of goals can be. For a much fuller discussion of the implications of the somewhat cryptic labelling of the factors here, see Rowe's article, or his 1977 book, The Anatomy of Risk. Rowe gives as his basic process of weighing these factors: "(1) direct gain-loss analysis; (2) indirect gain-loss analysis; (3) cost-effectiveness of risk reduction; and (4) reconciliation of risk inequities." p. 961 in the article.

A 1967 Department of Commerce study led by Richard Morse investigated the feasibility of electric-powered vehicles, especially in light of the problem of air pollution. The study included a careful listing of the administrative and economic principles relevant to such a decision. These principles are listed here in order to show the immense difficulties in accurately operationalizing such public problems within inductive models.

1. Policies should permit decisions to be as decentralized as possible.
2. Policies should be flexible and consciously experimental.
3. Policies should attempt to expand future "freedom of choice."
4. Policies should seek to minimize administrative complexity.
5. Policies should seek to attain firmer control by recognizing relevant distinctions.
6. Policies should strive to improve means to measure and monitor pollutant emissions, concentrations, and effect. Ability to measure and monitor lies at the heart of virtually all pollution control.
7. Policies should be coupled with careful economic research and system experimentation.
8. Policies should emphasize learning on the part of the public, industry, and government.
9. Policies should take into account possible major risks and contingencies.
10. Policies should strive to be equitable.
11. Policies should realistically take into account their leverage over the events they seek to control.
12. More efficient control can normally be obtained by incentives that depend on the variable one desires to influence rather than by incentives that depend on a related variable.
13. Payments of subsidies are subject to the following problems (in addition to cost-allocation problems):
    (a) There is no "natural origin" for payments or subsidies.
    (b) Payments or subsidies violate feelings of equity.
    (c) A "gimmick" is introduced into the tax system.
14. Policies should take into account "spill-over" costs and benefits.
15. Policies should consider the possible impacts of pollution reduction on alternative forms of medical care.

Quoted in Laurence H. Tribe and Louis L. Jaffe, Environmental Protection 1971, p. 300-301.

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