APPLIED THEORY OF RULE-BOUND SYSTEMS
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ABSTRACT *Human behavior is often governed by sets of rules. A successful theory of rule bound systems should be able to predict the properties of the system thus governed, by study of the properties of the rules. Systems analysis seeks similarities among fields of study. Rule-bound systems analysis derives from social anthropological study of cultural systems, economic analysis of regulatory systems, analysis of legal systems, and from formal logics and algebra. The theory has value for problems of understanding historical change and development, and as well for design of rule bound systems, a task which arises in legal and economic reform.*

OUTLINE

I. INTRODUCTION: PRINCIPLES AND RELATIONSHIPS TO FIELDS OF STUDY

At the turn of the previous century, the physical sciences were about to experience a profound expansion of their theoretical foundations, and productive ability. Thus in the early twentieth century, responding to the limitations of classical mechanics, the foundations for quantum mechanics were laid. Social science today is in a very similar condition to classical mechanics a century ago. Indeed, the statistical techniques used in social sciences are themselves essentially adaptations from classical mechanics (or the similar techniques of statistical biology). Many problems are properly treated with these techniques, but the inability of social science to deal successfully with others of obvious importance is also well accepted. As a well known example, the population explosion predicted several decades ago to have swamped the earth by the 1990s, missed not only the magnitude, but even the direction of change in population growth rates. But in recent decades, an alternative approach has been developed. In an initial test, this alternative approach successfully predicted the relative direction of changes in population growth of Western Europe and (certainly well within an order of magnitude) the rate of change of that growth, over a 1000 year time period. Like quantum mechanics, this alternative is structural, and uses a different combinatorial foundation from the classical approach. The present approach has origins in several fields.

I.A. Foundations in Analysis of Law

To identify the subject of the systems theory of rule bound systems (RBS) it is useful at the outset to distinguish it from jurisprudence. Jurisprudence is a positive study of which rules "ought" to occur.[1]. In contrast, the purpose of rule bound systems analysis is to understand why a particular set of rules exists, and to be able to know in advance the effect of adaptation of one or another set of rules. In an evolutionary sense, the subject seeks to understand why some sets of rules survive and others do not. Were the subject instead a positive study, then it would be restricted to analysis only of the possible survival of some pre-judged set of systems which "ought to" survive, and would thereby lose much of the possible subject matter and its sources of scientific validity. In addition, a positive theory is almost by definition not useful for analysis; instead, a positive theory must itself be analyzed to see whether its assertions are correct. To understand the distinction, note that in one example given below, the Bank's policy statement on electric sector lending is a positive assertion, against which conditions are tested using concepts and techniques of rule-bound systems analysis. This research also differs from jurisprudence in that the present subject, the theory of rule bound human systems, is ultimately a mathematical subject. The paper later discuses why that is true, and the nature of the mathematics which would (or more accurately, does) comprise this subject. Relationship to existing mathematical work in social anthropology and in computer logics (temporal logic) is briefly noted below.

[1] *Black's Law Dictionary*, 5th Edition, 1969. See also Paragraph i.1 in the lecture of Friday, December 24, 1762, in *Adam Smith, Lectures on Jurisprudence*, edited by R.L. Mech, et al, Liberty Classics, 1982.

The subject matter of the theory of rule-bound systems incorporates legal and judicial systems, but it also incorporates other human systems of rules which may not be explicitly embedded in legal systems. For example, the present subject includes human cultural systems of rules, such as marriage rules, and it also includes economic systems. It is true that in modern societies, these systems of human rules, in particular, are often subsumed by the legal system. But the theory of rule-bound systems does not assume that all subsystems of human rules necessarily become included in the legal system. If so, this would be a very strong result, necessary of proof and ultimately very challenging to many existing legal systems and especially to many existing political systems.

This observation especially shows why the present subject differs from the study of rules by Joseph Raz[2], who characterized legal systems as those which "*claim authority* to regulate all forms of behavior" (emphasis added). Many important systems of law make no such claim. It is not merely that some "western" systems regulate private behavior by permission, as Raz suggests. Instead, a significant portion of the activity of a legal system may actually go toward enforcing exclusions of authority, such as happens in the American system. On the British system see a similar conclusion by A. V. Dicey[3]. Raz (page 171) also states that for a legal system to be in force "...the courts must regard ordinary citizens as required to be ideal law-abiding citizens and judge them accordingly." Certainly in American law, and probably in the British tradition of common law generally, there is no such rule. The criterion in criminal law for example is whether the accused has violated the known specific acts defining a crime. The accused may have acted in truly horrid ways by community standards, but would be innocent of the crime accused if the commission of the specified acts is not proven. It is arguable that human history has spent the last several centuries specifically discarding the kind of encompassing legal systems assumed by Raz, and especially discarding those which command all to conform to "ideal" behaviors. It seems peculiar to define the positive study of law in a way that only encompasses systems we presently regard as totalitarian. But in any event, the theory of rule-bound systems avoids this trap in part by not being a positive theory at all.

Scottish economist Adam Smith used a positive definition in his study of jurisprudence, but his study of economics was more concerned with forming notions of actual rules, and of predicting the consequences of particular rules of behavior. Smith showed how these behaviors form a system with predictable effects on economic efficiency and creation of wealth. For example in *Theory of Moral Sentiments* Smith cites mechanisms by which individuals form rules by observation and experience in a society. In his more famous

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[2] Such as in J. Raz, *Practical Reason and Norms*, Princeton University, Press, 1990, page 151.

[3] A. V. Dicey, at Chapter XV, of *Introduction to the Study of the Law of the Constitution*, reprinted 1982 by Liberty Classics

work *The Wealth of Nations* he then analyzes the consequences of people acting according to particular patterns of behavior, which we have come to think of as rules of self-interested rational action.

Other economists have also studied the interaction of rule-bound systems and economic systems. Buchanan identified constitutional economics as a separate area of study: "...constitutional economic analysis attempts to explain the working properties of alternative sets of legal -institutional - constitutional rules that constrain the choices and activities of economic and political agents, the rules that define the framework within which the ordinary choices of economic and political agents are made."[4] Friedman similarly summarizes:

> "The economic analysis of law involves three distinct but related enterprises. The first is the use of economics to predict the effect of legal rules. The second is the use of economics to determine what legal rules are economically efficient, in order to recommend what the legal rules ought to be. The third is the use of economics to predict what the legal rules will be."[5]

Other economists have worked in these same directions, including several in well known works.[6]

Historical analysis of the economic effect of legal rules is also related to the systems theory of rules. For example, Horowitz analyzed how the dynamic economic growth of the United States in its first eighty years was driven by judicial reinterpretation of legal rules which affect commerce.[7] He shows that the result was a more dynamic system which allowed capital formation. Nelson[8] similarly showed how the pre-

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[4] James M. Buchanan, "Constitutional Economics", pages 134-142 in Eatwell, et al. (eds.) *The New Palgrave "The World of Economics"* W.W. Norton 1991.

[5] David Friedman, "Law and Economics", pages 371-380 in Eatwell, et al. (eds), *The New Palgrave "The World of Economics"* W.W. Norton, 1991.

[6] Von Hayek analyzed the existence of the legislative function in democratic societies, such as in F.A. Von Hayek *Law, Legislation and Liberty* 3 volumes from 1973 to 1979, University of Chicago Press. Posner applied economic analytical techniques to understand why particular rules of law exist and how they function; see Richard Posner, *Economic Analysis of Law*, Little, Brown, 1986, and also "A Theory of Primitive Society, with Special Reference to Law", pp 1 - 53 in *The Journal of Law and Economics* vol. 23, no. 1. That paper contains a section on "Legal Process" in which Posner presents conclusions regarding flexibility of legal rules, and contains a concluding paragraph which asserts a relation between the time available for a system to evolve and the stability of the rules, similar to the ideas found here. Coase and Calabresi analyzed how rules of tort law operate to create socially efficient results. See for example R.H. Coase "The Problem of Social Cost" pages 1-44 in *Journal of Law and Economics* Vol 3, October, 1960, and G. Calabresi "Some thoughts on risk distribution and the law of torts", in *Yale Law Journal*, volume 70, March, 1961.

[7] Milton J. Horwitz, *The Transformation of American Law 1780 to 1860*, Harvard University Press, 1977.

[8] William E. Nelson, *Americanization of the Common Law, The Impact of Legal Change on Massachusetts Society, 1760-1830*, Harvard University Press, Cambridge, 1975.

revolutionary legal system of the American state (which was then a British colony) of Massachusetts was designed to promote stability of a system of status-based wealth, using a notion of community. But the post-revolutionary system evolved rules that instead allowed more fluid relationships and economic growth in a more monetized and dynamic economy.

Thus the topic of the theory of rule-bound systems is not merely of academic value. As an economic policy, reinterpretation of an existing legal system may be a less capital intensive policy instrument to achieve growth. With the extensive modification of economic law now occurring in many parts of the world, the possibility of encouraging growth by use of rule analysis in connection with or even in substitution for capital spending is a development tool.

I.B. Foundations in Economics and Anthropology

Anthropology, particularly social anthropology and structural anthropology, have also sought to abstract general rules and then to find the consequences of existence of such rules. For example, Ballonoff defined the purpose of mathematizing cultural analysis this way:

> "... the study of culture, defined as the study of rules and their consequences ... must be capable not only of describing the rules, but of correctly predicting their consequences on material objects subject to their operations. ... it should also be possible to predict the properties of systems using the rules, and the conditions under which such systems may exist and would be observed".[9]

While Ballonoff did not explicitly use an "efficiency" formulation such as is common to economics, that study went on to describe the structures of marriage rules, to predict when particular rules would exist or occur, and to compute (demographic) properties associated with the existence of such rules. Therefore, except that this study did not attempt the positive program of which marriage rules "ought" to be used in particular societies, it did otherwise fulfill the definition of Buchanan and of Friedman as defined for economic analysis of law. It describes rules, shows the function of rules, and predicts the existence and consequence of existence of rules.

Note that economics is also not limited to the study only of hypothetically "rational" actors -- existence is also relevant. For example, J. Hirshleifer in his classic micro economics textbook[10] has this as his first sentence "Economics concerns decisions - choosing among actions". He elaborates "... economics as a science is not irrevocably wedded to the rationality postulate. When an alternative that proves more useful

[9] From page 1, in P. Ballonoff, *A Mathematical Theory of Culture*, Monograph No. 40, Austrian Society for Cybernetic Studies, 1987.

[10] J. Hirshleifer, *Price Theory and its Applications* 4th Edition, 1988, Prentice Hall.

comes along it will be adopted instead"[11]. Many of the studies cited here fit both of these concepts. The purpose of rules is to affect human choices of actions. But, most studies cited here are based on an "existential" description of the rules, rather than a presumption of rationality (or its absence) in the use of those rules.

The concept of existence is very important in theories of rule bound systems. Predictions are tested against what is found to exist, while actions of persons following (or avoiding) rules within particular systems also cause events (or objects) to exist. Thus both Posner and Ballonoff test their theories by describing theoretical structures, and then compare to what actually exists. Friedman simply included predictions of existence as a defined aim of the subject. Conclusions related to efficiency of the operation of rule-determined systems are deduced from such existential descriptions. It may be that when rule-bound systems are described existentially, then predictions of the existence (including of the duration, etc.) of a particular system are associated with analysis of the consequences of that system on material efficiency which results from following it.[12]

Closely related to both existence and efficiency are matters of system size. System size issues arise in several different forms. For example, in standard microeconomic analysis of production in a competitive market, it is assumed that there are sufficient producers that none is large enough relative to the size of the market to determine their own price. But how many producers is enough so that none is large enough to dominate the market? Some literature suggests that the number may be as small as two -- this is certainly one interpretation of the "theory of contestable markets". On the other hand, the standard textbook analysis of the case of "few" producers (oligopoly), two producers (duopoly) and one producer (monopoly) strongly implies or directly asserts that system behavior dramatically changes as system size (measured by number of actors) becomes smaller. Economic analysis of monopoly also shows that system size (as counted by number of producers) is related to both efficiency of production and the total size of the market. For example, the condition known as "natural monopoly" arises when the total size of the market is found within the declining cost portion of the average cost curve of a single producer. This kind of condition in turn has consequences for development policies. Leibowitz[13] argues that small national or territorial size creates the possibility that

[11] See page 7 of Ballonoff 1987 cited above.

[12] This property is shared by all of the above studies, including that of Ballonoff which was constructed in part from a microeconomic resource allocation framework.

[13] A.H. Leibowitz, *Defining Status, A Comprehensive Analysis of United States Territorial Relations*, Martinus Njhoff Publishers, 1989. The citation is but a small part of the subject of the text cited. This work can be read as a detailed analysis of change in rule-bound systems (the pre-existing cultures of people in U.S. territories) when a common set of rules (the U.S. Constitutional and legal system) is deliberately superimposed.

the local market is insufficiently large even to support an efficient local monopolist. Therefore, in a small economy export may be required to sustain an industry at all. Ballonoff[14] similarly discovered that the size of the Jamaican business community may be small enough that prohibitions on interlocking directorates acceptable for larger economies could hinder company formation in Jamaica. These kinds of claims are clearly predictions about not only size and efficiency but also existence. Thus, conclusions about market efficiency that seem axiomatic for large systems may have radically different implications when used to form policy (i.e. to determine rules of behavior) for small systems.

Interrelation of system size and existence is also found in analysis of cultural systems. In analysis of marriage rules, Ballonoff[15] used the concept of "minimal structure" to find the smallest self-replicating structure which maintained the existence of the rule. The parameters of this structure then were found to relate to the operating population statistics of any size system following the rule, not only of the theoretical minimum sized system. The argument used to derive this result was based on possibility densities, in a manner similar to thermodynamics. Thus while the underlying possibility distributions of cultural systems are not those of thermodynamics, this similarity of theory construction shows that similar efficiency arguments apply to cultural analysis as well.

Issues raised above can generally also be rephrased in the form of the adequacy and consistency of a description. For example, if a culture is described to have a marriage rule of a particular type, but the population size is described to be smaller than the minimal structure for that rule, one would question if the ascription of the rule to the culture is correct. Or, if someone describes a market as "competitive" and then tells us there is only one producer, then at the least many other empirical questions must be raised, and probably we would reject the description as correct.

Issues of logical consistency, adequacy and completeness of description arise in many cultural, legal or economic contexts. For example, one could conceivably construct a kind of "completeness" theory based on methods such as used in the Russian folklorist V. I. Propp's *Morphology of the Folktale*, and from this infer existence of as yet undiscovered examples of the cultural form, or the content of incomplete texts. It is arguable that the "structural analysis" of the French social anthropologist Claude Levi-Strauss is essentially application of a completeness theory for descriptions. Ballonoff (1995)[16] demonstrated that the fact that

[14] In a report to the Inter American Development Bank on a proposed Competition Act for Jamaica, 1991.

[15] See Ballonoff, 1987 cited above.

[16] See P. A. Ballonoff, "More on the Mathematics of Rule-Bound Systems" *Cybernetics and Systems*, 26:129-132, 1995.

cultures are often taken as unique literary objects does not make them unable to be analyzed. In contrast, the rules structure of the system is subject to analysis, and such analysis can derive predictions of properties which may be tested against empirical observations.

I.C. Related Literature in Cultural Mathematics

Several approaches exist for devising a mathematical treatment of, or theory for, culture. Most have been efforts to improve description; a classical problem of anthropology. In contrast, RBS has created a body of work treating cultural structures and their properties by drawing inferences on possible measures based on the described structures[17]. A theory of culture focusing on cognition was recently published by Ezhkova[18]. RBS therefore differs from descriptive mathematical treatments in that it relies on strong inferences from mathematical properties, in a way that makes it a true theory in the classical scientific sense, and differs from the work of Ezhkova in that it deals with structure rather than cognition.

Perhaps best known is the long history of treating kinship terminologies with mathematics and logics, similar to those developed for linguistics. Though in some ways related, RBS is not a reformulation of that work; instead it provides substantially new techniques and insights. The earliest paper of the kinship approach is that of Macfarlane in 1882[19]. Mathematical analysis of marriage systems, in addition to and in a more general way than kinship terminologies, was inspired by Levis-Strauss' 1949 work *Elementary Structures of Kinship*. Study of marriage systems with the mathematics of group theory is represented by work of H. White[20] following Weil's appendix to Levi-Strauss' 1949 book. This interest in groups as a means of analysis of marriage systems has indeed created a vigorous literature. P. Courrege[21] implemented Levi-Strauss'

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[17] See summary at Ballonoff 2000a.

[18] Ezhkova, Irina, 2002 "Challenges of Cultural Theory: Theory of Cognitive States" pages 423 – 437 in Trappl, R. (ed) *Cybernetrics and Systems 2002*, Vol. 1, Austrian Society for Cybernetic Studies, Vienna; and Ezhkova, Irina, 2004, "The Principles of Cognitive Relativity, Rationality and Clarity: Application to Cultural Theory", Cybernetics and Systems: An International Journal, Vol. 35 No. 2-3, March-May 2004, pp. 229 – 258.

[19] Macfarlane, A., "Analysis of Relationships of Consanguinity and Affinity" in *Journal of the Royal Anthropological Society* Vol 12 pages 46 – 63 (1882). Much like the modern trend, even in 1882 the mathematician Macfarlane referenced theories of language in developing his treatment of an anthropological subject.

[20] White, Harrison 1996 "Models of Kinship Systems with Prescribed Marriage", in Lazarsfeld, O. F. and N. W. Hendry (eds.) *Readings in Mathematical and Social Sciences,* Prentice Hall, New York, and White, Harrison 1963 *An Anatomy of Kinship,* Prentice Hall, New Jersey.

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[21] Courrege, Philippe 1965, "Un Modele mathematique des structures elementairs de parente", in *L Homme* Volume 5

approach for kinship systems, while more recently Read[22] has summarized and expanded on the tradition of kinship algebras. A recent summary of important approaches is also found in Ottenheimer and Feinberg[23] (2001). Efforts to "simulate" kinship systems, or generate their effects through simulation, are documented in the work of Read[24] or Ottenheimer[25]. In contrast to those works, RBS is also not an effort at kinship simulation. RBS is also not a study of "semantics" following the work of Lounsbury[26], nor of "componential analysis" as summarized in Kronenfeld[27]. Interest in the study of graphs of relationships of kinship or marriage within a given culture is represented by the works of D. White[28] which predict specific maps of relationships in a particular culture; White indeed is interested in graphs of other than just kinship relationships. RBS, while

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No 3 – 4, pages 248 – 290, (1965), translated to English by D. Read as pages 289 – 338 in Ballonoff, P. A. (ed.) *Genetics and Social Structure*, Dowden, Hutchinson and Ross, Stroudsburgh Pennsylvania (1974).

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[22] Read, Dwight, 1984 "An Algebraic Account of the American Kinship Terminology", in *Current Anthropology* 25:417 – 440; Read, Dwight, 1990 "An Expert System for the Algebraic Analysis of Kinship Terminologies" in *Journal of Quantitative Anthropology*, 2:353 – 393; Read, Dwight 2000, "Formal Analysis of Kinship Terminologies and Its' Relationship to what Constitutes Kinship" in *Mathematical Anthropology and Cultural Theory*, Vol 1 No 1, November (2000), http://www.mathematicalanthropology.org .

[23] Ottenheimer, Martin and Richard Feinberg, 2001, *The Cultural Analysis of Kinship: The Legacy of David Schneider*. University of Illinois Press.

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[24] See Read 1990 cited above.

[25] Ottenheimer, Martin 1992, *Modeling Systems of Kinship 3.0* (Computer Program in QuickBASIC with documentation). Dubuque: Wm. C. Brown Publishers

[26] Lounsbury, Floyd (1964) "The Structural Analysis of Kinship Semantics" pages 1073 – 1093, in H. Hunt, ed. *Proceedings of the Ninth International Congress of Linguists*, Mouton, The Hague.

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[27] Kronenfeld, David (1996) "Componential Analysis" in D, Levinson and M. Ember, eds., *Encyclopedia of Cultural Anthropology*, Vol 2 pp. 224 – 228 Henry Hold and Co. New York.

[28] White, Douglas 2002 "Network Analysis and Social Dynamics" in Proceedings of the European Meetings on Cybernetics and Systems Research 2002, R. Trappl (ed) *Cybernetics and Systems 2002* Volume 1, pages 420 – 425; also White, Douglas, Jason Owen-Smith, James Moody and Owen Powell, 2004a. "Networks, Fields and Organizations: Scale, Topology and Cohesive Embeddings" in A. Lomi and P. Pattison (guest Eds.) Special Issue on the Mathematical Representations for the analysis of social networks within and between organizations" in *Computational Mathematics and Organization Theory* January 2004, available at http://eclectic.ss.uci.edu/~drwhite/pub/cmot-3.pdf; and also White, Douglas, Jason Owen-Smith, Walter Powell and Kenneth Koput, 2004b "Network Dynamics and Field Evolution: The Growth of Interorganizational Collaboration in the Life Sciences" to appear in *American Journal of Sociology*, also available at http://eclectic.ss.uci.edu/~drwhite/pub/SFI-WP2003ajs.pdf

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embodying graphs in certain ways, is also not a study of graphs as such.

The relationship of RBS to the "kinship algebra" approach is that the ability for representation of marriage rules, in certain ways as symmetric groups, is one of the facts also exploited for inferences in RBS. An example of how far the kinship approach can be applied to empirical research on an actual terminology, yet still not reach the inferences of RBS, can be found in Denham and White[29] which follows the work of John Atkins, represented by Atkins and Denham[30], much of which in mathematical form was never published. The illustrations in Denham and White clearly have symmetry properties, but they do not draw the kinds of population and historical inferences available from RBS

In contrast to the above approaches, RBS also analyzes the consequence of a simple claim of the existence of a rule. The means of describing that claim ethnographically may involve use of kinship and/or of graphs in certain ways, but the main subject of RBS is not the graph as such – it is the further inferences that are enabled by certain specific properties of the graphs. Likewise, RBS is not an analysis of "kinship." It is a system of inference for the consequences of claiming the existence of a particular system of "marriage" rules. Such claim of existence may have itself arisen from some analysis of "kinship," including perhaps as described by the authors cited here, but the origin of that description, if any, is not the basis for RBS.

The subject is thus instead properly described as characterized mathematically as the "Theory of Minimal Structures" (TMS) and their consequences, not the study of kinship, nor of graphs, but for simplicity here will always be referred to by the more general term rule-bound systems (RBS). Though RBS is not limited solely to structures at their minimum size, as also discussed below. This development, based initially on of the mathematical analysis of marriage systems, and more generally phrased as a foundation for a theory of culture, was developed by Ballonoff[31]. Ballonoff not only described the structures of cultural systems of marriage mathematically, but also derived quantitative inferences from the mathematical description, leading to making testable and tested predictions on measures that could be and have been empirically observed on the populations governed by cultures with particular marriage systems. The principal formal development of the theory has been on systems of marriage, but broader applications justifying the idea as a "cultural" theory will be demonstrated in the work.

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[29] Denham, Woddy and D. White (2003) "Multiple Measure of Alyawarra Kinship" in D, Read, (ed) special issue of *Field Methods* (to appear), also available at: http://eclectic.ss.uci.edu/~drwhite/pw/MultiMeas03a.pdf

[30] Atkins, John and Woodrow Denham, "Comment" on "Genealogical Structures and Consanguineous Marriage Systems", in *Current Anthropology*, 22(4): 390-391

[31] See Ballonoff 1976a, 1982a, 1982b and 1987 cited above.

These diverse approaches to analysis of culture are high complementary. One way to understand the relationships is through the use of lattice theory -- the treatment by Maria Luisa Dalla Chiara and Roberto Giuntini[32] of formalism and interpretive vocabulary for orthomodular lattices and quantum logics is useful here. They develop parallel structures for what they describe as the algebra of a lattice structure, and the semantics of a related lattice structure. This kind of distinction between structure and semantics is well known to anthropologists. Chiara and Giuntini describe construction of orthomodular lattices in which the definition of the complement, in both the algebraic and the semantic lattice, is in terms of "reachability;" given a rule of reaching (moving) from one state to another, under that rule some states may be unreachable from other states. These sets of states may form complements of each other, and if so, the lattice of all such states and their complements is an ortho-complemented lattice.

The configurations of marriage systems as studied by Ballonoff[33] define exactly states (sets of configurations) which are reachable from each other and sustain the existence of the rule, and states which do not allow to reach the sustainable states (because they are below a minimum size or configuration), hence are not capable of sustaining the rule. For any given rule, these sets are therefore complements of each other. Thus the set of states with configurations below, and the set of states at or above the minimum for a given marriage rule form a complemented lattice (indeed an ortho-complemented lattice) of all possible configurations of marriage relationships, under the algebra (and semantics) of allowable and disallowable marriages of that rule. Thus, as will be noted below, various algebraic objects in culture theory, including possible operators for marriage rules or kinship classifications (terminologies) can form filters over lattices of possible relationships, selecting certain portions for particular purposes. As well, the analogy, mentioned in Ezhkova[34] to a Hilbert space for cultural theory is not mere speculation; orthomodular lattices allow construction of measure spaces and in particular, of Hilbert spaces. Likewise also, it is thus not surprising that the approach of Ballonoff has led to computing measures on specific observables, thus allowing testing of the theory on real cultures.

[32] Dalla Chiara, Maria Luisa and Roberto Giuntini 2001, *Quantum Logics*, in arXiv:quant-ph, 2001

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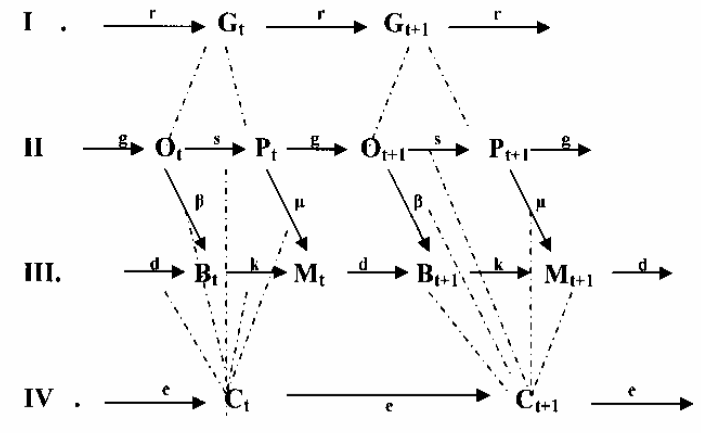
[33] See Ballonoff, 1987 Appendix I cited above.

[34] See Ezhkova 2002 cited above.

TABLE 1: Schematic Notation Used Here

Symbol	Indicates
k	Kinship terminologies and labeling rules
μ	Marriage rules (culturally recognized)
M	Graphic or relational representation of marriages under a marriage rule
ß	Sibship rules (culturally defined offspring cohort groups)
B	Graphic or relational representations of sib groups under the rules
d	Genealogical descent (culturally recognized)
g	Genetic descent (real biology)
s	Mating selection rules (for biological mating)
e	Cultural evolution operator
E	The ethnographer's description at a given time
D	Real biological operators (e.g. genetics, real time demography, other physical processes)
P	The biological parents in G at time t of offspring that become part of the population at G_{t+1}
O	The actual biological offspring in G_{t+1} of the parents P in G_t
G	The set of real individuals existing at a given time, "culture bearers" or "culture members"
C	A vector of the operators or other objects constituting a representation of "a culture"

It is convenient to illustrate the relationships among the various approaches noted here with sketches using the formalism described in Table 1, above. Since the various papers use their own notations, the schematic notation of Table 1 is used (invented) for the present discussion. The notation is not rigorous, though the various approaches referenced do have rigorous versions of the concepts implied. Because the study of kinship and marriage systems is better developed mathematically, it offers a convenient case for posing the current discussion. Thus, the schematic notation reflects typical kinship or marriage notions. This is not meant to imply that kinship and marriage system analysis is all that is relevant to a theory of culture. Note that while the symbols are not given in the table with a time index, any of them might be treated as a time series, or a point in time measure, or the set of relevant objects existing at a given time, as appropriate to the application, either in subscript or functional form. Also while many illustrations in the sketches below seem "discrete," this is only for ease of illustration; most or all of these notions can be considered as continuous time process, and indeed applications of the theory to



processes on historical and even evolutionary time scales are cited in several places below.

The basic sketch, above, is a summary diagram similar to that commonly drawn in papers of Ballonoff to show the relationships among real-time populations (represented as Gt at time t), the sets of "marriages" M on that population under marriage rule μ, leading to genealogically assigned offspring of those marriages in sets B under descent rule d and sibship rule ß The pairs of B_t and M_t symbols with the same time index indicate that the individuals in the relationships are each subsets of the same population G at the time indexed. That is, the relations (graphs, operators, etc.) denoted by M and B are different relations among the same set of people. A sequence is shown, with time progressing from left to right. In the work of Ballonoff (especially 1976, 1987), the objects M, B, μ and ß, and their properties, are cultural constructs resulting in predictions of measures on the real population G. Thus these relations and sets might also be considered "genealogical" concepts as described by Read (2000). Symbols P and O depict the real biological relationships that exist among the individuals in population G, at the respective times. These symbols thus also represent for example, real biological relationships, in the sense described by Read (2000). Ballonoff's papers do not explicitly analyze equivalent systems on O and P, though in the matrix operator formulation[35] (Duchamp and Ballonoff 1974), empirical relationships could also be formulated. The sequence of C operators summarizes the vector of cultural concepts (μ, ß, M, B, etc) at the time of observation. This is intended as a sequence of vectors representing the culture (e.g. set of operators, rules, classifications) at a point in time. These operators, rules, classifications, and the like, change over time under the influence of Ezhkova-type analysis, under operators e (the e operators are not drawn on all the sketches, and should be envisioned along the arrows between C symbols) [36].

Numerous authors[37] have also studied systems of operators that describe possible relationships that can be formed at a given time under cultural rules or operators. Ballonoff[38] has also studied combinatorial implications of these operators for measures that might be made on G from the point of view of effect of operators M and B. Read[39] has studied the ways in which cultural operators or rules as found in vectors C,

[35] Duchamp, Thomas and Paul Ballonoff, 1974, "Matrix Operators Arising in Marriage Theory", in Ballonoff. P.A, (ed.) *Genealogical Mathematics*, Mouton, Paris

[36] See (Ezhkova 2002, 2004). cited above.

[37] H. White (1963, 1996); A. Weil (appendix to H. White 1963); Ruheman Barbara 1945, "A method for analyzing classificatory relationship systems" in *Southwestern Journal of Anthropology* Vol. 1 pages 531-576; Ballonoff (2000a, see summary); Duchamp and Ballonoff (1974); F. Lorrain (1969), and many others.

[38] Especially Ballonoff 1976 Chapters 5 and 6, 1982a, 1982b and 1987).

[39] See Read 1990 cited above.

can and do produce particular empirical sets of relations of the sorts M or B on the population G at a given time ("instantiation"). Read (1990) and others discussed in detail by Read, have studied the algebraic and logical properties of the structure of symbol systems (kinship algebras) related to generating that instantiation, and are thus also engaged in the study of kinship, "k", not shown on this sketch, but used below. Ballonoff does not explicitly study either k or the process of instantiation. The system k at a time t would however occur in the vectors C and thus be subject to study of formation and change by Ezhkova[40] In any particular empirical situation there are actual relationships created among individuals, allowed by the culture, and the graphic representation of those relationships has been studied by D. White[41]. Ballonoff[42] has laid the foundation for analysis of the transitions among vectors of the configuration space of possible graphs.

There are three different sets of measures identified in the sketch, those relating Line II to Line I ("top layer") those relating Line III to Line II ("middle layer"), and those relating Line IV to Line III ("bottom layer"). The top layer, connecting G to the sets P and O, represents ordinary biology and other real time processes. Thus the measures in the top layer are those of genetics or demography, and in other applications, could include measures of economic efficiency, rates of materials flows, etc. These reflect normal physical measures, and are in a literal sense, the "thermodynamics" of the system. Normal biological measures in the top layer are typically governed by density functions related to the Stirling Number of the First Kind. This is a classical subject that many authors have studied.

The middle layer is the effect of combinatorial properties of the operators B and M, on the measures that might be made on G. These measures have been studied by Ballonoff [43] and have been shown to reflect use of the Stirling Number of the Second Kind, due to the properties of the mappings implied by the relationships or operators. This fact leads to the ability of Ballonoff to make successfully tested predictions on measures that are associated with the existence of certain cultural systems. (If the inference above relating the structures studied by Ballonoff to orthomodular lattices -- that is, quantum logics -- is correct, then it may also be that this layer is quite literally a quantum theory. In any event, the idea should be familiar that different kinds of statistics, with different density functions, are needed to study thermodynamics –analogous to the top layer – and quantum or structural mechanics – analogous to the middle layer.

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[40] See Ezhkova, (2002, 2004) cited above.

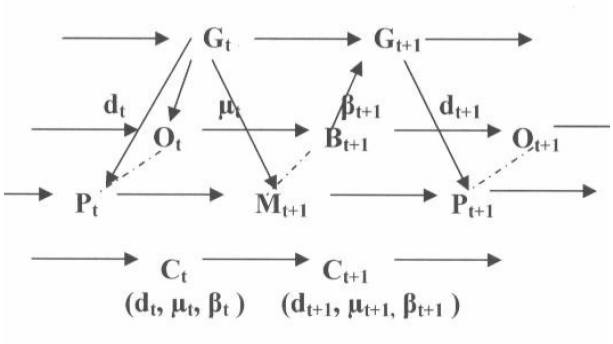
[41] See D. White 2002 and D. White et al 2004a and 2004b previously cited.

[42] See Ballonoff, especially 1982a, 1982b and 1987, and 1987 Appendix I.

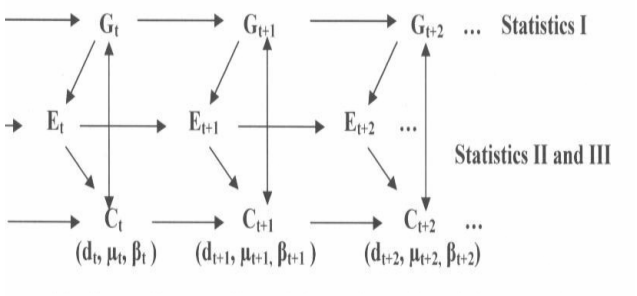
[43] See references in previous footnote..

The bottom layer, meant to indicate measures on the evolution of the cognitive system, is studied by (driven by) the measures defined by Ezhkova[44] though also influenced by the measures studied by Ballonoff, as noted below in relationship to a singularity existing in one of the Ballonoff equations.

The above representation does not explicitly depict the obvious fact that the P and O operators discuss real relationships among the same sets of individuals that are classified culturally by the B and the M or similar cultural constructs. The individuals subject to operators P, O, M and B are all subsets of G at a given time. Thus, "pick up" the structure by the "back bone" sequence of the G's. The result, looked at from the end, is a truss-like structure, "hung" from the sequence of G's, with alternating sequences of pairs of P, M, P, M, etc. on the "front" edge, and of O, B, O, B, etc. on the back edge. This sketch also illustrates how the C and the G structures evolve in coordination with each other.



Finally therefore, remove everything from the sketch but the C and the G representations, and add one new representation: the ethnographer's description. Let this all evolve over time, and an "ethnographic view" emerges from the sketch, also implied by the work of Ezhkova[45] who noted that the observer of such systems can also be modeled by the same technique as used to model the culture itself. In effect, the individuals in G are one example of the "machines" modeled by Ezhkova that generate the vectors C and cause them to evolve over time. The elements of G are the "culture bearers" of the Culture C. More accurately, in Ezhkova's work each member of G generates (and continually regenerates) its own vector C.



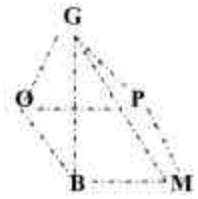
In this ethnographic view, ordinary (real) population and genetic statistics (Statistics I, which is the "top layer" noted above) occur on the top edge, as the arrows move forward from G_t to G_{t+1}, etc. Statistics II, per work of Ballonoff, (the "middle layer" noted above) occur on the measures implied by the arrows both between the C structures as time moves forward, and also between the C and the G structures "sideways" across the truss structure. The movement "forward" of the C vectors from time t to t+1

[44] See Ezhkova 2002 cited above.

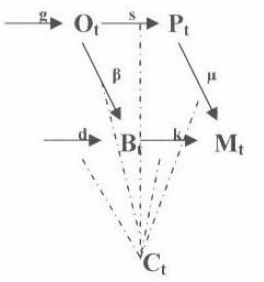
[45] See Ezhkova 2002, 2004 cited above.

etc. is governed by Statistics III (the "bottom layer" noted above) per work of Ezhkova[46]. The prediction of empirical relationships actually observed among individual members of G_t generated by C_t is studied by the instantiation rules of kinship algebra, by graphs, and by other means.

Now look at the last sketches, left and below. The figure labeled as the "Real System" shows the relations among G, M, B, P and O, based on the above sketch. This summarizes the physical representations and the cultural relations actually occurring, at a particular time. The figure "Cultural System" illustrates the relationship among the operators or rules of relationship specified by d, e, k, μ, and ß. Since the cultural system consists entirely of operators (rules, etc.) its properties may be studied by mathematics. This is where one finds results such as that mathematical groups exist on marriage rules. Properties of terminologies, as studied by kinship algebras, are also properties of the cultural system. Instantiation is prediction or computation from the cultural system to create (predict) a particular instance of the real system, and/or, if considered as an operator on the lattice of all possible cultures C given a particular G, the process of instantiation uses the cultural system as a filter on that lattice.



REAL SYSTEM



CULTURAL SYSTEM

Now consider that G evolves forward under the real evolutionary operator(s) D, and that C moves forward under the cultural evolutionary operator(s) e, and that the effects of both e and D must occur on the same real systems at the same time. These therefore clearly constrain each other. The study of those interacting constraints is what Ballonoff[47] conceptualizes as the study of this entire evolving process, a theory of history. Ballonoff[48] has applied inferences of this sort to study the population history of Western Europe over a 1000 year period, and has used the same framework to study separation on bio-evolutionary time scales of social structures of insects and mammals – including, of course, humans.[49]

The movement forward of the cultural system, that is, the study of the algebra of cultural relations over time, forms a filter on the huge lattice of relationships possible on a population G given cultural rules C, and thus also forms a filter predicting the possible or likely observable forms of future cultural structures realizable

[46] See Ezhkova 2002, 2004 cited above.

[47] See Ballonoff 2004 cited above.

[48] See Ballonoff 19821 cited above.

[49] See Ballonoff 2000b cited above.

in the real system Simply stated, analysis of the mathematical properties of the systems that can comprise various sets of cultural rules allows prediction of the empirical cultural structures, and certain of their measurable properties, likely to be observed in reality.

I.D. Related Literature in Theory of History[50]

Cultural theory can allow prediction of history or historical processes (see also Ballonoff 2004). The vast majority of all history written today still employs the empirical historical method devised by historians in the nineteenth century, although the origins of this methodology date back to the scientific revolution of the seventeenth century and the belief that all knowledge is derived from observation. The empiricist paradigm emphasizes a rigorous examination of primary source materials in an attempt to reconstruct the past as it actually was. Historians employing this method of inquiry are to be objective and ultimately search for a truth that they believe can be discerned about the past. Perhaps the greatest proponent of this school of thought in the twentieth century was the renowned English historian, G.R. Elton, (1967, 1987)[51]. Critics of this school of thought attacked its early proclivity for focusing on great leaders and events in history to the exclusion of everything else. Empirical historical analysis is associated more with method than theory.

Karl Marx (1848) [52] provided the first and perhaps the most enduring challenge to the empiricist paradigm and developed the only theoretical historical model that attempts a predictive view of history. Although Marx was somewhat successful in developing a methodology that explains the process of human social evolution, as E. Wright (1992) [53], explains, he never wrote his historical theory in a single text, but scattered his ideas throughout the bulk of his writing. Marx espoused a materialist conception of history in which all aspects of a society were based on its economic structure. The Annales School in France represented another group of historians who attacked traditional, empirical history and attempted to discredit the history of events by adopting economic and cultural analyses that rejected the primacy of political history. Founded in 1929 by Lucien Febvre and Marc Bloch, the Annales School developed the first interdisciplinary approach to history and devised a "total history" that explored all aspects of historical reality. Later Annalists like Emmanuel Le Roy Ladurie (1978) [54], developed new avenues of analysis by focusing on the mind-sets or

[50] This section was written with the assistance of Annette Finely-Crosswiite, Associate Professor of History, Old Dominion University, Norfolk Virginia

[51] Elton, G. R., The Practice of History. London: Methuen, 1967, (1987)

[52] Marx, K., *The Communist Manifesto: a modern edition*. Ed. E. J. Hobsbawn. London: Verso, 1998.

[53] Wright, E. (1992)

[54] Ladurie, E. Le Roy, *Montaillou: village Occitan de 1294 à 1324*. Paris: Éditions Gallimard, 1978.

mentalities of past societies. Annalists also employed the use of quantitative methodology in their work and at one point incorrectly predicted the end of narrative history.

While there are too many schools of historical thought to mention here, one common problem that many historians faced in the twentieth century was that "theory of history" was commonly associated with having to justify or explain the idea of progress. Indeed, with the collapse of communism at the end of the Cold War and before the events of September 11, 2001, many historians like Francis Fukuyama (1991) [55], began to revive the Hegelian idea of history as rational process with an intelligible purpose and completion. Fukuyama even argued from the vantage point of 1991 that with the triumph of liberal democracy, the history of the West had reached its logical destination.

Given the troubling events of the opening of the twenty-first century, Fukuyama's perceived triumph was short-lived; however, in that all theory based on the idea of progress remains not only simplistic but also incapable of meaningful predictive measures. The mere fact that a particular set of structures occurs in some historical sequence does not mean that the sequence will repeat, or can be used to predict sequences of "stages" in the future of some other human group in which the existence of some similar structure may be observed. Instead, it is necessary to examine the particular rules in use, and to determine whether and how they are changing, in order to predict future states of configurations. Because the rules determine the possible sequences of structures, and because the statistical theory implied by these rules uses the Second Stirling Number, not the First, then supposedly "dynamic" theories based on thermodynamic models (which all inherently use the distributions based on the Stirling Number of the First Kind) do not determine the viability of structures nor therefore their historical duration. Therefore, in particular, "chaos" and other theories which are based on thermodynamic models are not predictive of historic sequences. But because cultures do depend on real physical processes, physical models of those processes relate to the physical flows of materials as configured by the cultural objects. Therefore, models of efficiency (as from microeconomics or thermodynamics) can be used, in connection with other facts, to predict limits of possible presence of certain cognitive structures (rules systems). However, the fact that an analyst of or a participant in a system is confused does not imply that the system is in chaos in any technical sense.

Perhaps those historians attempting to explain historical change have been most successful when adopting cultural theory as part of their analyses. Borrowing ideas and methodologies from the social sciences, historians such as Natalie Zemon Davis (1975) [56], John Bossy (1985) [57] and Carlo Ginzburg (1980)

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[55] Fukuyama, Francis, "Liberal Democracy as a Global Phenomenon," *Political Science and Politics* 24 (December, 1991): 659-64.

[56] Davis, N., *Society and Culture in Early Modern France*. Stanford: Stanford University Press, 1975.

[58], have been successful, for example, in discerning the relationship that existed in the sixteenth century between religion and social structure. All three trace a debt to Emile Durkheim (1915) [59] through modern social anthropologists that include Arnold van Gennep (1960) [60], Victor Turner (1969) [61], and Clifford Geertz (1973) [62]. Davis (1982, p. 267) [63] argues that historians can learn from anthropologists in four main areas: the "close observation of living processes of social interaction; interesting ways of interpreting symbolic behavior; suggestions about how the parts of a social system fit together; and material from cultures very different from those which historians are used to studying."

A "theory of history" drawn from cultural theory is thus a necessary result of analysis of cultural structure and the conditions for the existence of structure. Ballonoff[64] argues that cultural theory is in fact a hard physical science, dealing with real natural, including historical, events in the real and natural world. Most historians are engaged in description, and, thus, concentrate on specifying the status of the temporal descriptions at a given time. In contrast, cultural theory, and especially the mathematical theory of anthropology, is concerned with the properties of the atemporal operators ('the culture' in some sense), their relationship to the possible paths of the intertemporal operators, and the empirical results of the operation of these on the possibility of observing particular conditions of the temporal operators. As such, the mathematical theory of culture is a scientific predictive enterprise, not merely a descriptive one, and is therefore also a theory of history.

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[57] Bossy, J., *Christianity in the West 1400-1700*. Oxford: Oxford University Press, 1985.

[58] Ginzburg, C., *The Cheese and the Worms*. Trans. J. and A. Fedeschi. Baltimore: The Johns Hopkins University Press, 1980.

[59] Durkheim, E., *The Elementary Forms of Religious Life, a study in religious sociology.* Trans. J. W. Swain. New York: G. Allen and Unwin, 1915.

[60] van Gennep, A., *The Rites of Passage.* Chicago: Chicago University Press, 1960.

[61] Turner, V., *The Ritual Process: Structure and Anti-Structure*. Chicago, Aldine, 1969

[62] Geertz, C., *The Interpretation of Cultures; selected essay*. New York: Basic Books, 1973.

[63] Davis, N.,, 'Anthropology and History in the 1980s' in T. Rabb and R. Rotberg, eds., *The New History: the 1980s and Beyond.* Princeton, New Jersey, Princeton University Press, 1982.

[64] Ballonoff 2004, pp. 272-273

Finally, recognizing RBS or RBS as a "theory of history" has one more important advantage. It also directly answers the post-modern challenge to the historical profession. Post-modernists argue that historical objectivity is impossible and there is no reality outside of language. Roland Barthes (1967) [65], for example, wrote that written history is nothing but a form of narrative that collapses the story-discourse distinction. As such, history is nothing but a personal construct of each historian, or more simply, historiography. The mathematical theory of culture offers a compelling way out of the post-modern trap by proffering a historical theory that goes far beyond the reality simply of language by accommodating itself to the reality of cultures, by study of the implications of their existence and of the claims that they exist.

I.E. Concepts for Analysis of Rule-Bound Systems

It is now useful to define some terms for analysis of systems of rules. Apply the term "transformational system" to whatever organization or institution does the natural, physical work of the system, that is, the operating system. Label as "reactive" those institutions or organizations which regulate interactions among transformational systems and their environment. Label as "logic" whatever rules govern the reactive systems.

Note that these terms derive directly by analogy with what's called temporal logic of reactive and concurrent systems.[66] Temporal logic of concurrent systems is a mathematical means of analyzing operating systems of computers that are simultaneously running different programs, which programs may also be using common data sources and generating results used by each other. Temporal logic alone is a theory of logic which involves formal operations which draw inferences about conditions of the past or future states of a system, based on the logic of that system. Such analysis is a necessary part of a fully developed theory of rule based human systems. Each human system has its own past, present and future. Logic of operations of rules over a time dependent system must account for these temporal states. Although in this paper only used by analogy, the mathematics of parallel processing is closely related to that of cultural systems. It has been shown for example that the minimal structure of a marriage system is isomorphic to a "butterfly architecture" – the most efficient means of processing classificatory information in a system of parallel processors.[67] Thus this also anticipates results such as those found in studies of actual systems of cultural information processing. Lyon[68] for example found that the Pakistani family was an efficient information processing system, whose

[65] Barthes, R. *Elements of Semiology.* Trans. A. Lavers and C. Smith. London: Cape, 1967.

[66] Z. Manna and A. Pnueli, *The Temporal Logic of Reactive and Concurrent Systems, Specification*, 1992, Springer-Verlag, New York.

[67] See Paul Ballonoff "Does Structure Matter" pp. 682-686 in R. Trappl (ed.) *Cybernetics and Systems* '96 Volume II, Proceedings of the Thirteenth Meeting on Cybernetics and Systems Research.

structure is also used as an analogue for other cultural systems. This discussion is continued in Part IX below, as applied to cultural systems that are often believed to be not susceptible to analysis since they are "unique". However, their structure can be analyzed and conclusions drawn, as also exemplified by the cited work of Lyon.

Indeed the notion of "survival" of a rule *requires* explicit treatment of temporal existence, co-existence, and continued application of rules and of the effects of rules. The mathematics known as the temporal logic of reactive and concurrent systems does temporal analysis very rigorously for computer programs. Legal analysis does this kind of analysis in its normal course, it merely does not do so using formal mathematics. To create a cultural mathematics[69] it was similarly necessary to deal with temporal sequences, and with problems of structural relations determined at a point in time by the existence of rules in some temporal sequence. Economic analysis often does not repeat its temporal assumptions in each application, but is clearly making such assumptions in the elementary texts.

The purpose of rule-bound systems analysis is creation of useful theory, not just description. To understand what a full theory of rule based systems would produce, impose an axiom: the logic of the system has to be capable of representation as a mathematical group. This has very precise meaning in mathematics, which is literally met in several examples of rule bound systems cited below. In cultural theory several authors have each shown that when you can represent marriage rules abstractly, that the rules are also representable as symmetric groups[70], that is, by similar mathematics to that used to describe the symmetry of crystals or the nature of patterns in works of art.[71] The work of Ballonoff on cultural mathematics shows that important

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[68] See for example S. Lyon "The Pakistani Punjabi Family and Household as a Core Information Processing System" pp. 271 – 275 in R. Trappl, (ed.) *Cybernetics and Systems 2004*, Vol. I, Proceedings of the European Meetings on Cybernetics and Systems Research 2004.

[69] Such as cited in references of Ballonoff, 1987 cited above.

[70] The classical anthropological literature on the oral culture of Australian preliterate tribes led to discovery that cultural rules have the property of mathematical groups. Although almost never given credit for the discovery, this was apparently first written out by B. Ruhemann, "A Method for Analyzing Classificatory Relationship Systems", pages 531 - 576 in *Southwestern Journal of Anthropology*, Vol. 1, 1945; also in "Purpose and Mathematics: A problem in the analysis of classificatory kinship systems", pages 83 - 124, in *Bijdragen*, Vol. 123.

[71] See for example A. Weil "On the Algebraic Study of Certain Types of Marriage Laws (Murngin's System)", which originally appeared in the French edition of Levi-Strauss' *Elementary Structures of Kinship*, Presses Universitaries de France, Paris, 1949. The work was reprinted in English as an appendix to H. White, *An Anatomy of Kinship*, Prentice Hall, 1963. White's work especially applies group mathematics from the viewpoint of crystal theory to a more general class of marriage rules.

population parameters of a cultural system are related to the order (size) of the mathematical group which represents the marriage rule[72]. For temporal logic the sets of operators representing past and future conditions of an operating system each form a symmetric group[73]. Thus, the axiom is very reachable.[74]

Since mathematical cultural theory is already described elsewhere[75] here we consider what it might mean to impose the "group axiom" on representation of an empirical system of rules, such as legal system. The practical meaning as applied here is somewhat weaker than a mathematical group: as used here the "weak group axiom" asserts that a system must be computable based on the stated rules, that inferences from these computed forms be capable of consistent evaluation as true or false, and that outcomes have practical meaning in the system to which applied. (We do not discuss the additional possibility that the result of each computation have a unique inverse, which condition would be required for a more complete analogy to a mathematical group; probably such systems also at least have computable "inverses" in some meaningful sense, though their uniqueness might be harder to assert. Seeking only systems which have unique inverse however is also a distraction from the present discussion. Actual mathematical groups do exist in rule bound systems, as summarized above. The purpose of the immediate discussion is thus heuristic, not mathematical).

In simple summary, our "weak group axiom" means a system must be consistent, complete and computable. Thus, the "weak group" logic would not just be a generator of strings, like sentences. The phrase "this contract is valid" may be a correctly constructed sentence, under a rule of construction of proper strings. But

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[72] See P. A. Ballonoff, "Mathematical Theory of Social Demography", pages 101 - 112 in Trappl, ed., *Progress in Cybernetics and Systems Research*, Vol. X, 1982a; and "Mathematical Theory of Social Demography, II" pages 555 - 560 in Trappl, ed., *Cybernetics and Systems Research*, 1982b.

[73] See Chapter 3 of Manna and Pnueli, 1992, cited above.

[74] Furthermore, when it is reached, the results are very powerful. For example, in analysis of cultural rules of marriage, it is known that such rules can be represented as mathematical groups, as cited in other footnotes of this paper. It was also know than presentation of such groups as matrices of zeros and ones was possible, and that the diagonal of such matrices in certain conditions was always filled with zeros. Ballonoff has demonstrated that this seemingly trivial fact has powerful consequences: due to theorems in the mathematical theory of group representations, the population statistics of any sized system operating under a rule with group characteristics, is computable from knowledge only of the order (size) of the smallest group which represents the operation of that rule. That is, the demographic characteristics of any culture are computable (predictable) from knowledge of the form of cultural rules alone. See P. A. Ballonoff "Comparison of Rule-Bound Systems Theory to Traditional Systems Theory" *Cybernetics and Systems*, 27: 317-326, 1996. See Ballonoff 1982a and 1982b for development of the theory which does the demographic computations.

[75] See especially citations in Ballonoff, 1980, 1982a and b and 1987 cited above.

"this contract is not valid" may also be correctly constructed. In a semantic system with concrete references to actual objects, and with consistent rules of construction, both can not be true at once. Under an effective legal system following our "weak group axiom", not all of the strings one can generate that are grammatically correct are going to be acceptable under the law. There is some means of relating the empirical content of a statement to the way that content is evaluated within the legal system, in a sentence of given structure.

Place these ideas in a legal context. Within a given system, the law must say things that are mutually consistent with each other; it predicts what will happen, legally, in a particular factual situation. This ability to evaluate particular facts in particular contexts is important : what is true under a given system of law is not arbitrary. It is not just that a judge makes a decision, and it could be any decision, because that person is the judge. The decision maker must follow various established rules in reaching the outcome. Imposing the heuristic requirement that the theory which one constructs has the properties of our axiom therefore also imposes strong conditions, which conditions legal systems do often have.

One implication of application of the axiom to analysis of legal systems seems startling: the future is predictable. But this is not such a surprising result when one considers its practical meaning. Take a potential contract to a lawyer and ask "is this contract is valid? Will it be possible to enforce the contract or to get damages?" The legal opinion in this example is really a prediction, usually a very accurate prediction if the lawyer is competent, about the future.[76] The prediction is reached by proper application of the rules of that system to the relevant facts.

The next implication is that to make such predictions possible, a system of communication of past case outcomes is necessary. In pre-literate societies, this may take the form of recitations of "tales". In literate societies, this would normally take the form of written decisions. Also, since a judge does not have arbitrary authority, a written decision enables the judge to state (and others to verify) whether the decision is made according to the law.

Judges in turn must have some means of generating their conclusions, some rules of analysis. *Stare decisis* refers to a judicial rule of interpretation respecting a prior decision. Usually it means respecting the prior decision of a higher court, but it is also a kind of consistency rule. This rule, which is part of common law traditions, is almost a direct interpretation of the group axiom as applied here. The use of the principle of *stare decisis* makes a strong statement about the consistency and predictability of the system. Prior judicial decisions, known because they are written, become "analogics" or surrogates for explicit rules, which give the

[76] The cultural example cited in Ballonoff 1980 and 1982 above used post-diction, that is use historical of data and show that you can predict from the structure to the measures, and vice versa. One could use a theory predictively with more confidence, if it works postdictively.

ability to compute a result in a new case by applying the reasoning of older cases to the new set of facts, using the prior decision by analogy. The description of the use of precedent as analogy for deciding future cases is not new to the literature on jurisprudence. For example, M. J. Horowitz summarizes a debate between philosophies of United States Supreme Court justices on the role of analogical reasoning in the common law. One need not take any position on what may be the "proper" role for such analogy, to recognize that all sides of this debate acknowledge the presence of analogical reasoning in an important form. For present purposes what is important is that the presence of analogical reasoning, or something similar, is implied by our "group axiom", and is found in empirical reality.[77]

Richard Posner[78] has argued by example that legal systems must be looked on as coherent structures whose rules must be interpreted in the context of other rules in the same system, not merely as separate entities to be compared against each other on an ad hoc basis. That result, which is also a property of the "weak group axiom", is one of the critical conclusions of the paper. By conducting an analysis of the full systems of US and UK law, Posner concludes that the "English legal system is closer in an important sense to the Continental legal system than it is to the American" (page vii). This result parallels two observations of the present paper. One, as noted earlier, the work of Raz on legal rules is not a general theory of legal rules, since it defines law in a narrow way which excludes American law. In fact, Raz seems unaware of the differences between UK and American law; his theories are perhaps better viewed as applicable to Continental law. Second, this paper later analyzes aspects of Philippine law as examples of how to apply rule-bound analysis. Philippine law provides another example of how looking only at pieces of the law and not the whole system can lead to wrong conclusions. For example, in appearance, Philippine law looks "American" in use of forms and language, and also seems to be a "common law system" in ways similar to American law. But when looked at more closely, the powers of the Philippine Congress are much closer to those of a Continental type legislature or parliament; the Philippine Congress is unrestricted in ways that Raz might find familiar; and Philippine law is much more of a system of Code law, including many elements drawn from Continental Civil Law, than a common law system.

Related issues have been raised by Attiyah in comparing American and British systems of law.[79] The use of *stare decisis* in the British system of law evolved as judges more or less created their own powers even when Parliament had made no direct grant, and all began acting according to rules like *stare decisis*. While

[77] M. J. Horowitz, *The Transformation of American Law, 1870 - 1960*, Oxford University Press, 1992, at pages 204 to 205

[78] Posner, Richard, *Law and Legal Theory in the UK and USA* 1996 Clarendon press, Oxford.

[79] See P. S. Atiyah and R. S. Sommers *Form and Substance in Anglo-American Law*, Clarendon Press, Oxford, (1991).

the British have an extensive system of common law, Parliamentary Acts, and related historic documents, there is no written British constitution, in the sense that the United States or many other countries have a written constitution which purports to be the body of law from which all else flows or must be consistent. Thus for reasons of consistency, completeness and computability, it is a serious question whether or not common law and written constitutional systems can exist simultaneously. Either the two systems of law must govern different subject matters, or, one system must govern the other. In the American context, the later has generally become the case -- where constitutional and common law provisions conflict, the constitutional provision will prevail.

An interesting if perverse form of support for many conclusions here was given by Mander[80]. Mander is an unabashed critic of technological progress, *per se*, as a cause of demise of many "native peoples" around the world. The example he particularly elaborates is that of the Constitution of the Iroquois Nations. Mander argues that the Iroquois had a constitutional form of government with an elaborate civil and criminal code long before formation of the United State Constitution or its predecessor document, the Articles of Confederation. But says Mander, several elements of modern life are a vital attack on the Iroquois system. Despite the present existence of written copies of the Iroquois Constitution (such as easily found on the Internet), that code was inherently an oral document; the existence of a written form is itself a compromise of the structure and operation of the culture of transmission. An oral code is shared only by and among culture bearers. But clearly, when a code is only oral and thus only accessible to people with special knowledge, then that code is of very limited use in a more dynamic environment which must deal with many "outsiders", each of whom may require clear and certain knowledge of the rules of action within the society. Thus, Mander's seemingly romantic opposition to written culture is an implicit corroboration of one argument of this article, that written codes enhance system viability in a more open environment. The written Internet version of the Iroquois code, if accurate, recognizes that change in the code may be necessary but does not contain any explicit rule of self-change; the lack of definition self-limits the ability to adapt to change in predictable ways.

This supports the conclusion of Ballonoff (1994) [81] that presence of a workable rule of self-modification is a requirement for a viable rule system in a technologically dynamic environment. Ballonoff (1994) placed results of earlier papers in the context of other bodies of research: jurisprudence analysis of legal rules, social anthropological analysis of cultural rules, and logical analysis of how operating systems process control rules. A primary conclusion was that formalized rule systems evolved within human systems

[80] Mander, J. , *In the Absence of the Sacred, The Failure of Technology and the Survival of the Indian Nations*, Sierra Club, 1991

[81] Ballonoff, Paul, "Theory of Rule Bound Human Systems" in *Cybernetics and Systems*, Vol. 25 No. 6, November-December 1994, pp. 837 – 860.

which must manage relatively more frequent technological and economic change. Therefore, these systems are subject to relatively more frequent need to change their own rules, and, therefore, the viability of such rule systems is closely dependent on their internal rule of how they change their own rules. At the level of the broader society, this is a requirement about the structure of the political constitution. At the level of a regulatory institution or judiciary, this amounts to a requirement that the system be self conscious about its own rules of decision, have self-conscious means of identifying those rules, and have previously published means to change both the rules of how decisions are reached and the rules stating substantive applications. In any particular political structure, these particular sets of rules could be distributed as legislative acts (laws), court decisions, or administrative actions.

Mander also suggests that the Iroquois constitutional code was the model for the American one. He argues that many features of the Iroquois code are also present in the American basic documents, including separations of powers among various constitutional bodies, specific duties of different bodies or officers, codes for election and removal of officials, and so forth. Indeed, most of these features are the essence of what is often referred to as "Western Democracy". Geographically the Iroquois are no doubt in "the West" (the Iroquois Nations exist in the north-eastern portions of North America), but culturally they are not, and if Mander's history is right then historically in many ways their code pre-dates, or arises independently from, "the West".

Thus, the Iroquois example together with other anthropologically documented and legal system examples cited, show that the theory of rule bound systems is not a matter of "West vs. East". The theory comprehends issues which relate to any system of rules.

II. EXAMPLE 1: APPLICATION TO A PROBLEM IN DEVELOPMENT POLICY

The International Bank for Reconstruction and Development, also known as the World Bank or simply the Bank, is one of a small number of intergovernmental institutions created after the Second World War, to encourage economic development through technical lending without being tied to the foreign policy of any particular country. Rather, the Bank proposes and carries out its own analyses and policies, while acting as lender of last resort for countries undergoing economic development. The Bank has been particularly interested in infrastructure development through physical projects, such as power plants and electric transmission systems.

In January, 1993, following an intense analysis of its own experience over many years, the Bank issued a new statement of policy.[82] This statement marked a significant departure from previous policy

[82] See *The World Bank's Role in the Electric Power Sector, Policies for Effective Institutional, Regulatory and Financial Reform*, A World Bank Policy Paper, The World Bank, 1993.

practices of the Bank, because it was stated neither in engineering nor economic terms. Rather, the policy requires that certain forms of regulatory structures and processes be in place, before lending will be undertaken for the electric power sector. This policy is expressed through several "principles", whose over-all impact is to encourage movement to greater independence and self-management of the power sector, using corporatization of institutions, privatization, competitive entry from foreign providers or managers, and other rather familiar techniques.

"Principle one" of the Bank's policy statement says that "A requirement for all power lending will be explicit country movement toward the establishment of a legal framework and regulatory processes satisfactory to the Bank". To do so, the Bank lists six criteria which must be met for this "principle one" to be met. These are: (1) a clear set of rules, known in advance; (2) rules actually in force; (3) mechanisms to assure the application of the rules; (4) conflicts resolved through binding decisions of an independent judicial body or through arbitration; (5) known procedures for amending the rules when they no longer serve their purpose; (6)a framework of regulatory incentives ... to support competition and induce efficiency.[83]

Of these six bulleted requirements, only the last, a framework of regulatory incentives to support competition and efficiency, is clearly derived from and based on economic and engineering considerations. The other five items are requirements about the form and functioning of institutions. Even more subtly, the requirements are not stated as requirements for any specific form of institution, rather they are requirements on what might be called the cultural form of the system, design requirements for how the system shall be constructed and operate. The importance of the "cultural design" nature of these requirements is reinforced by the only part of them which is institutionally specific, the reference to "an independent judicial body" or binding arbitration. Even this however does not specify the type of judicial body, only that it be "judicial" (presumably of a type which reaches decisions through application of known rules), and that it be independent (presumably of the entities about which decisions are reached, and also of direct political administration). But these features are also more a requirement for cultural design of the operations of the broader system, than for the specific form of any institution.

The Bank's electric sector lending policies are also interesting because a very similar set of conclusions arose from a completely independent line of research, related to the theory of rule-bound systems. This implies that the Bank's "principle one" especially may be a more general requirement for the efficient operation of an economy operating in a technologically dynamic and also politically charged environment. The papers of interest were presented by the present author as a series. Ballonoff (1988)[84] was written as the result of an

[83] See the policy statement especially at pages 60 to 61.

[84] P. A. Ballonoff "Is There a Role for Regulators in a Deregulated or Less Regulated Economy?", in R. Trappl (ed.) *Cybernetics and Systems '88*, 525 - 532.

internal self-examination of the role of a regulatory institution of a US state.[85] The institution had recognized that it had a statutory mandate to act, yet faced competing philosophies as to how to act. Review of the technical economics literature led to two conclusions. First, given a choice, for economic reasons the best utility regulation is no regulation (except the application of antitrust policy). Even in the presence of natural monopoly, direct economic regulation of the sort often practiced by US utility regulators can not achieve lower price nor greater efficiency than would an unregulated market; at most, the effect of regulation is to reallocate economic rents away from the holder of the natural monopoly, to other supply entities. Thus, a second conclusion was that if despite the first conclusion a regulator is forced to act, then the best policy it can follow is to permit entry (or even encourage entry). If the regulator must set price, then it should do so in no more restrictive form and by the same criteria as would be applied in an antitrust proceeding. By this means, the regulator would meet its statutory requirement to act, and at the same time reach as closely as possible to the economically efficient result which may occur if the political requirement to regulate had not been imposed.

The above cited paper relates to the Bank requirements in several ways. It concludes that the purpose of specific utility regulation must be to support competition, which therefore also encourages efficiency. These are both specific criteria of the Bank. The paper also concludes by describing policies which are not dependent on the form of the institution. Rather, these are policies which could be enforced by either a quasi-judicial regulator, or by a court, or by an administrative agency. All that is presumed is that the broader legal system contain antitrust rules which confine the actions of these various forms of judicial bodies. Such requirement for a system of known rules, in place, is also a requirement of Bank policy. The 1988 paper differed from the Bank policy largely by specifying that the broader rules that should be applied by the regulator were antitrust laws (that is, competition laws).

Ballonoff (1990)[86] outlines the broader context of rules and institutions which exist in the U.S. and which carry out major features of the Bank's policy. The paper describes the broader system of rules, their functions and their inter-relationships. It describes the criteria under which particular forms of rules are selected and applied, some of the forms of regulatory error which can occur when applying rules, and why these may occur. It describes some of the mechanisms which assure enforcement of rules, and some of the limits to rule enforcement placed by the larger political structure of a federal system. Thus, this paper implicitly addresses the first four of the Bank's listed requirements for its policy, as applied to a particular system (the

[85] The Illinois Commerce Commission is the public utility regulator for the state of Illinois. In 1987 the executive director (chief of the staff) of that Commission requested staff members to analyze what was "good regulation". The 1988 paper cited here was a published version of the present author's response to that question.

[86] P. A. Ballonoff, "Is the U.S. Free Market Really Free (Of Government)?", in *Cybernetics and Systems: An International Journal*, Volume 22, pages 425 - 441 (1991)

U.S. regulatory/legal system). Finally, the discussion earlier related to the conclusions of Ballonoff (1994) compares to the requirement for a viable means to change the rules of a regulator when the old rules no longer apply, which is the Bank's requirements for an acceptable legal or regulatory system; it is the fifth listed requirement in the summary above.

Thus, rule-bound systems provide a framework in which important matters of development policy may be analyzed. Rule bound systems analysis finds the kinds of rules which may occur, shows why they are important, and provides means of describing and analyzing particular systems of rules and their consequences. That a major institution, the World Bank, has independently derived very similar conclusions, also confirms the objective of the third paper: "to understand why which set of rules is in fact selected, and to be able to know in advance the effect of adoption of one or another set of rules, ... to understand why some sets of rules survive and others do not".[87]

III. EXAMPLE 2: APPLICATION TO INSTITUTIONAL STRUCTURE ANALYSIS

Application both of RBS analysis and of the Bank's policy for power sector lending requires, among other analysis, consideration of the consistency and coherence of a legal and regulatory system. This section discusses an example based on the regulatory institutions of the Philippines, as they existed prior to 2000, emphasizing how principles of rule-bound system analysis help to understand that system.

The basic legal and regulatory rules of the Philippines are set forth in the Constitution of the Philippines and in various legislative acts, in executive orders which have the force of law, and in court decisions which together form an internally consistent legal framework. The Philippine legal system (decisional system) operates as if it were a common law system. It draws upon case law primarily from Philippine court decisions, but also from other common law jurisdictions in cases where local law or precedent do not determine a result. The Philippines have a history of public service regulation which can be traced back to legislation from 1903, creating municipal franchises. The Philippines therefore have a history of modern regulatory structures which is as long as or longer than that of most other countries using similar systems, including longer even than in some American states. A general description of the Philippine system and its functions can be given with terms common to describing similar systems in other countries. But as should be expected for any system with a century of history, functioning of the Philippine system is particular to the country.

The current regulatory structures are based on authority created by legislation passed in 1936, and as subsequently amended (especially Commonwealth Act CA 146 of 1936 and Presidential Directive PD 1206

[87] See the first page of Ballonoff 1992.

of 1977). This series of laws defined the powers and functions of the institution currently known as the Energy Regulatory Board (The Board), itself created in its present form in 1987 (by Executive Order EO 172). The Board is a quasi-judicial/quasi-legislative body with price regulatory powers, duties and procedures resembling those of similarly functioning bodies in other jurisdictions. In 1973, legislative power over utility franchises was delegated to the National Electrification Administration (NEA, created by PD 269). The most recent (as of this writing this discussion in 1998) major change in regulatory structure was passed in December, 1992, when the Philippine Congress created the Department of Energy, granting that Department responsibility for energy policy and centralizing price regulatory functions in the The Board (Republic Act RA 7638, the DOE Act).

Other legislation is also relevant and is cited below as required. A principal body of legislation important to understanding Philippine administrative systems, and especially the meaning of "transparency" in such systems (that is, of the clarity of the rules and consistency of their application), is the Administrative Code of 1987 (hereafter referred to as the "Code"). The Code is important because it sets at least minimum standards for transparency for all agencies with regulatory or rule making powers. Two sections of the Code are relevant for this purpose. At Book VII, Chapter 2 Section 9(2) the Code requires that "if not otherwise required by law, an agency shall, as far as practicable, publish or circulate notices of proposed rules and afford interested parties the opportunity to submit their views prior to the adoption of any rule". This section therefore applies to all of DOE, The Board and NEA when acting in any rule making capacity.

The Code also applies to government corporations when acting in governmental capacity, and therefore also applies to the National Power Corporation (NPC), which is in any event part of and responsible to the DOE. Code Book VII, Chapter 3 then also lays out more detail for processes of administrative agencies in contested cases. Both The Board and NEA have prescribed rules for their electric energy hearings processes, which meet or exceed Code standards, therefore which directly govern their processes without further reference to the Code. DOE is however governed more directly by the Code. As an example of this, in 1989 the NPC intentionally complied with Code requirements by holding a series of public meetings around the country, prior to issuing a final version of its rules implementing co-generation legislation known as EO 215.

The specific authorities and duties of The Board and DOE are summarized in Tables 1 through 4 below, giving specific legislative citations. Table 1 shows the basic powers and duties of The Board, which are generally to regulate prices for all electric energy public service companies, to regulate service quality including efficiency and safety, and including a broad investigative power with power of subpoena, all subject to safeguards of proper notice and hearing processes. Table 2 summarizes the basic powers and duties of DOE, which can be more clearly seen as oriented toward policy formation, to meet the broad purposes required by law. Because the statutes specify the particular structure and allocation of duties in DOE in some

detail, Table 3 summarizes the specific duties of the Bureaus within the DOE.

Table 4 summarizes and compares the differences in basic powers of the two agencies. Table 4 is better understood if viewed with reference to certain Opinions issued by the Philippine Department of Justice (DOE) in reply to questions posed by the DOE. In particular, in Opinion 98 of the 1993 series, the DOJ stated that the differences in powers and duties of the two agencies lie in their differences in essential functions and processes. While a more superficial reading of the broad purposes of the two agencies makes them appear to be in overlap and conflict, Table 4, reflecting Opinion 98, shows that their basic functions are decidedly different. DOE is predominantly a policy making body acting largely through administrative processes, but generally lacking direct jurisdiction. The Board, while also having some rather prominent quasi-legislative functions and duties, is predominantly seen as a quasi-judicial body with direct jurisdiction and enforcement powers.

Now notice that thus far the "description" given has really been application of the principles of completeness, analogy and prediction, stated in the summary of the theory of rule-bound systems. Tables 1, 2 and 3 lay out the details of the system. The DOJ Opinion 98 states a conclusion, which was based on rules of common law and precedent applicable to the Philippines. Opinion 98 then takes the form of a general rule or precedent. Taken literally, the Opinion makes a statement only about those two lines in Table 3 shown by a "**". But taken as a rule of inference, Opinion 98 provides an analogy which applies to all of the simple assertions represented by Table 3 on DOE authority, leading to the general conclusion that DOE is a policy body while The Board is a predominantly judicial body. These are simple seeming but very strong conclusions, whose truth depends on rather deep chains of logic which apply principles of analysis of rule bound systems. Note that below I also use these principles to predict some possible future properties of this system.

It is therefore a reasonable over-simplification to use European parliamentary terms to describe the Philippine DOE as "the Government's cabinet agency which forms policy" and the The Board as "a special court with investigative powers". DOE has resource policy and resource planning authority, energy regulatory policy authority, and various related administrative and research duties. The Board has price and certificate regulatory authority (subject to DOE policies when DOE has properly issued rules for such purposes). DOE acts via publication of rules and policies using administrative proceedings governed by the Code. The Board acts in formal proceedings governed by notice and hearing, with jurisdiction and powers appropriate to such processes.

Although authority of each agency is defined by the law and interpreted by the Department of Justice such as in its Opinion 98, in some areas there is an apparent overlap of authority. It is useful to describe several examples. The Board has authority over certificates of public convenience and necessity for private

utilities (other than cooperatives), while NEA has similar responsibility for certificates for cooperatives. The essential purpose of a certificate of public convenience is to define operating terms and conditions. However, DOE has authority to establish policy for utility operations. DOE can also establish policy related to market entry. The terms and conditions of service expressed in the certificate can also affect whether, as a practical matter, entry is possible, powers held by The Board or NEA.

Entry is also of course related to whether a franchise area is granted or to modifications of franchises, authority held by NEA. The Board must review costs in the process of setting rates, while DOE can issue policies which affect costs. The Board can not only review costs, it can and often does evaluate efficiency is determining whether a cost can properly be passed to consumers; DOE has explicit authority for many areas which result affect efficiency of electricity generation, including production planning, short and long term fuel mix, plant dispatch, operations policy generally, and many other areas. DOE is also responsible for strategic planning in the sector, both directly and through control of actions of NPC, all of which also strongly affect service efficiency and quality (areas of interest to The Board). The Board is responsible for price, which includes for review of costs for purchased energy such as from independent power producers (IPP's), but DOE establishes independent power producer purchasing policy and NPC implements this. Also, The Board would be responsible for any demand side management program rates or rate base elements, but DOE is responsible for conservation programs.

Despite what seems a daunting list of conflicting authority, it would be incorrect to conclude that the two agencies are necessarily in continual conflict. Rather, the differences in procedure and definitions of purpose of the two agencies can permit the result that no actual conflicts result. This because what the law requires is that where DOE has properly issued a policy rule on a subject matter, then The Board must apply that policy if lawful. Where DOE has issued no policy on a matter properly before The Board, then The Board proceeds with normal common law rules of precedent, etc. to determine the correct result in that case. The result would be that while both The Board and DOE can at times affect the same subject matter, there is an effective "sequencing" rule which assures that no conflicts of authority arise.

IV. EXAMPLE 3: APPLICATION TO INSTITUTIONAL PROCESS ANALYSIS

Principles of rule-bound systems analysis allow analysis without prejudging the merits of the answer in a positive framework. As an example, we continue the example of Philippine regulation, as it existed prior to 2000, emphasizing the transparency (predictability and intelligibility of outcome based on rules) of the system. Philippine energy price regulation is conducted by The Board. The Board is a non-constitutional body created by legislation, and can trace its origins to legislation dating to the early twentieth century. Executive Order 172 of 1977 created the entity currently named The Board under legislative limited term authority prior to establishment of the present Philippine Constitution. EO 172 primarily reorganized specific previously

legislatively created regulatory authority, a matter in any event within the executive authority, but did not create nor destroy any quasi-legislative or quasi-judicial powers. To do either requires an act of the Philippine Congress. The Board has its own sets of published procedural rules, published case decisions, and related case law dating from at least 1936, which form sets of predictable precedents for its action. All matters which reach the The Board therefore are potentially decidable based upon known rules of law and procedure, much as in any other common law jurisdiction.

The second Philippine energy regulator, the DOE, has responsibility generally for "non-price" matters including NPC planning, coordination among utilities, and energy sector policy generally. The DOE was created in December, 1992 under the Department of Energy Act (DOE Act), Republic Act 7376. The DOE is an administrative agency with powers to "formulate such rules and regulations as may be necessary to implement the objectives of this Act".

As such, DOE therefore falls under the Administrative Code of 1987, Book VII, Chapter 2, Section 9, Paragraphs (1) and (3):

> "(1) If not otherwise required by law, an agency shall, as far as practicable, publish or circulate notices of proposed rules and afford interested parties the opportunity to submit their views prior to the adoption of any rule. ...
>
> "(3) In the case of opposition, the rules on contested cases shall be observed."

More detailed rules for conduct of contested proceedings are then laid out in Chapter 3 of the Administrative Code, Book VII. The Chapter 3 rules are in general those of a quasi-judicial or quasi-legislative regulatory body in any common law jurisdiction, while the Chapter 2 rules for rule-makings are certainly at least the minimal requirements for transparent rule-makings.

Since The Board has its own rules which meet or exceed Code standards, the Code rules do not impose additional constraints on Board procedure. Similarly, when NEA is acting in a quasi-judicial or quasi-legislative capacity, such as deciding on its congressionally delegated franchise matters, it also uses transparent processes. However, in the electric sector DOE has neither other administrative processes nor quasi-judicial powers, therefore DOE is required to follow at least the above cited minimal Code administrative processes in rule setting. In 1989 NPC did follow the Code by holding public meetings prior to publication of the rules for EO 215. Code Book VII Chapter 2 Section 9 (1) however is rather vague about the public processes which should be followed in rule-makings. It is likely that as more frequent and complex rule-makings are used, that the vague language of the Code may not seem adequate. Therefore, the DOE should conduct a rule making whose purpose is precisely to set forth rules and processes for future DOE rule-makings.

DOE does not have quasi-judicial processes for complaints which could arise in the electric industry, nor for means of enforcing its rules and policies. Therefore complaints which arise about DOE processes

would likely be taken to the Philippine courts at present. But careful review of The Board electric industry authority shows that The Board already has transparent quasi-judicial processes, jurisdiction over the most of proper parties, and enforcement authority for proper policies of the DOE. Further, any party can make a complaint at the Board, and, therefore, certainly DOE can make complaints or other formal filings at the Board. Therefore, as a practical matter the DOE can enforce its policies by making such appropriate filings at the Board. Such enforcement would also therefore fall under transparent processes.

Court, Board and NEA rules of practice, procedure, evidence, and decision are published and enforced in a manner generally similar to those of other common law jurisdictions. As in other common law jurisdictions, the procedural remedy for failure to properly apply a rule (or to follow a contract) is appeal to the courts, or, where the rule is an order of, or in the jurisdiction of the The Board, by complaint before the Board. The Board enforces its own orders. Errors of the The Board can be and are corrected by the courts by normal appeals processes similar to other common law jurisdictions. In contrast, NPC has published rules for independent power producers (under EO 215) and the DOE have published rules for the BOT Law. Although DOE actions, if challenged, could be appealed to the courts, it is suggested that the Board is already structured as both the appeals and enforcement body for DOE policy, since Board has the appropriate jurisdiction, the Board is required to follow proper DOE policy, and since The Board (and not DOE) has the appropriate quasi-judicial powers and ability to impose remedies.

Transparency also requires analysis of processes for changes in rules. The Board has known rules and procedures for both establishing and changing any of its published rules, namely "notice and hearing". The Board can change price policies as evidence warrants, and set prices according to policies which The Board may determine, subject to proper notice and hearing. In so far "changing rules" relates to industry structure, the Bank's framework presumes that the ability to effect such changes may be specified to some named regulatory body. To the extent such body exists in the Philippines this body is DOE. The Administrative Code of 1987 provides for notice and public comment for major actions of policy when issued as rules, which is how DOE would so act. Assuming DOE uses Code processes, then changes in sector policy would also become subject to transparent process.

V. EXAMPLE 4: APPLICATION TO ECONOMIC PROCESS CONTROL

The theory of rule bound systems is applicable to systems of rules other than legal; including those which can affect economic and investment decisions. For example, electric power dispatch and power system coordination are themselves regulatory systems strongly governed by sets of rules, and therefore are also subject analysis using concepts of rule-bound systems. To illustrate this I describe below three models for economic dispatch of energy to meet instantaneous demands of a power system. These show that understanding how power systems can be structured is not merely a technical engineering nor economic

problem. Electric power dispatch is a very good example of a rule bound system which acts very much like a legal system, with a decision maker (called the system dispatcher) who makes continual choices of resource allocation questions, among competing potential providers, based on an explicit set of rules. Electric power system dispatch however is also a good example of a literal concurrent operating system of the technical sort, making electrical flows proceed in certain very technical ways. Thus, analysis of dispatch is very much a question for analysis of rule-bound systems, using similar principles to those discussed above.

Under Model I all power producers and all power buyers join a power pool, which is a contractual relationship comprising all power producing and power purchasing entities. There is a privately organized and operated single national market-based mechanism to set price for short term dispatch, to effect such dispatch, and effect billing at the market prices for each transaction. Transactions are subject to pool rules determined by a private contractually based association of all transmission and distribution entities, which also coordinates all long term generation expansion and transmission planning of all members. Model I is an artificial market device, structured to create dispatch according to market supply-demand curves on a continuous basis. Relative "bargaining power" of parties due to aggregate annual load or load shape, which would result in the contracts of Model II (below), do not affect dispatch decisions. While the actual dispatch would be a pure market (except for necessary considerations for voltage stability and system transmission security), it does not necessarily result in the same outcomes as pure economy dispatch because parties offering power pool purchase or sale prices may determine their offers using more than just than short term fuel economy information.

Under Model II power sellers and power buyers contract with each other as they deem, using the transmission system as an open access network (perhaps subject to appropriate transmission pricing under regulation. The central dispatcher applies contract rules to determine hourly priority of dispatch of each unit, up to the greater of the actual hourly loads or the maximum of capacity under such contracts. The central dispatcher applies rules such as determined in merit order dispatch (Model III below) for loads above the threshold in (2). This Model II, seeming the "pure market" solution, is likely to be affected by various policy constraints which affect formation of contracts, and also may have the problem of "lumpiness" of relative size of contracts and available production to market size, which would result in distortions from efficient market results. As a result, Model II is likely to result in dispatch which differs from pure economy dispatch (Model III) by more than just considerations of engineering stability. In particular, Model II is highly likely to result in contract order dispatch which places plants with higher short run marginal cost ahead of plants with lower short run marginal cost.

Under Model III the system dispatcher uses a rule of pure engineering economic dispatch from all available plants on each interconnected grid at any given moment. Dispatch is subject to exceptions only-existing contracts with energy type take-or-pay restrictions (which themselves will be subject to least cost

supply-substitution crediting or brokering requirements, without penalty providing the plant has also met its availability requirements), hydro best practice use of reservoir, geothermal best practice use of reservoir, engineering best practice voltage stability control conditions, any other demonstrable (and probably very rare) similar exceptions. All dispatch rules are set by a committee consisting of all generation, transmission and production entities to advise and recommend all such rules to the system dispatcher. Model III permits some necessary policy choices to be exercised explicitly, and to effect pure engineering economy from all remaining plants. Model III is based entirely on non-market decisions, whether by choices necessary to accommodate system stability, voltage control or other agreed technical factors, or by use of engineering criteria for measurement of current real time running cost which may however approximate some market information (short term marginal cost).

The point to be most noted here is that in their purest sense, Models I and II are each different versions of a "free market", and show that even competitive markets are strongly structured by assumptions about business practices, that is, about system rules. In an ideal world, including one which has a large enough market size, many players and infinite time (or numerous repetitions), all three models might on average have identical results. In reality, market size, past history, and especially the structure of the local rules as applied to the facts of recent local history, can cause each model to have very different actual results in any application.

VI. EXAMPLE 5: ANALYSIS OF EMERGENT SYSTEM PROPERTIES

One application of analysis of rule-bound systems is to identify possible emergent or future properties of a system of rules. This is especially useful to do when the system of rules is changing. Strictly stated, an emergent property of a system is one which arises from the operation of the system, but which was not directly described by the structure of the system nor intentionally designed as a behavior of the system. Rather, the property "emerges" from the operation of that system. Emergent properties are typically capabilities that arise from adaptive solutions of one problem, which properties also have totally different and otherwise unexpected capabilities in other applications; the unexpected capability is the emergent one. Here the term is used also in a looser sense of properties that would arise from partial implementation of system design, or from more complete logical analysis of contingencies inherent in the system design. In economic analysis one better known emergent property is that an economy meeting the assumptions of free market microeconomic static equilibrium also has high rates of technological progress in dynamic conditions.

In a study of regulatory reform, potentially emergent issues fall into four general groups: (1) regulatory issues which result from carrying out other structural reforms; (2) regulatory issues which result from carrying out regulatory structural reform; (3) regulatory issues which result from inconsistencies in law used to define regulatory reforms; and (4) regulatory issues that arise from incomplete carrying out of regulatory reforms. I again illustrate these using the Philippine example.

Emergent problems arise in the Philippine examples above in several interrelated, yet distinct, ways. One question of interest for investors is whether there is potential for regulation of IPP's should system behavior change. Following Philippine Department of Justice Opinion No. 95 of 1988, IPP's are not regulated by The Board. This occurs because IPP's do not hold themselves out to sell to the general public but instead sell to one entity, the National Power Corporation, and therefore IPP's are not public utilities under applicable law. This implies however that if IPP's were to hold themselves out to "the public", that they would become classified as public utilities and therefore would be subject to The Board jurisdiction. Also, in the same circumstances and for the same reason, such IPP's would likely also become subject to Philippine Constitutional limits requiring at least 60 percent domestic ownership of public utilities.

Note what would happen in the Philippine structure if a "pure free market" model of contracting or of pure market dispatch is applied, in which any producer could contract with any buyer. If such a structure were imposed, then any independent producer which decided to participate in that market could become classified as a public utility. A similar result could occur if legislation which allowed wheeling to (say) commercial and industrial customers over a certain size load, or even which allowed wheeling only to direct sale customers of NPC. Either definition of customer class could permit an interpretation of sales to "the public" in a meaningful sense, hence lead to classification of any producer who offered such sales (even if none were contracted or transacted) as a public utility. Another way IPP's could become classified as public utilities would be for redesign of the system dispatch to be done in a way that causes producers to be in a position of making offers to the public. This could occur in either of the "free market" versions Model I or Model II above, and could even occur in a pure economy dispatch model (Model III above) if the moment to moment dispatch were also to be the basis of matching customers to producers for transactions.

The second major way for emergent regulatory issues to occur is through the same regulatory processes described earlier. In fact, the discussion inherently assumes certain emergent properties in portraying DOE as a general policy body with The Board as essentially a court of first review for that policy. For example, in Table 3 there are nine distinct sections of the DOE Act which use the word "assist" in describing the duties of DOE to make policy. Only two of these shown with a "**" in that table, are cited in DOJ Opinion 98 of 1993, in which Opinion DOJ discussed the differences in jurisdiction of The Board and DOJ. This classification of duties is the basis for the argument that The Board is largely the judicial body, and DOE largely the Government's policy body. Reaching this conclusion depends on the validity of the claim that all DOE responsibilities described in the law as "assist" or similar verbs place DOE in the same relationship to The Board as do the two specified areas. On first glance the above conclusion seems reasonable, but as in any legal system, each action under a statute which has not previously been specifically tested by prior action under that specific portion of the statute raises the risk that some previously unknown legal problem may exist. Thus, the application of a rule of analogy in this case does not guarantee that the application is correct, until

tested by the operation of the system itself.

The above logic, in a more extreme form, is also the basis for the third means of emergent issue to arise. Legal systems are designed to resolve conflicts. Conflicts can arise from differences in interpretation of statutes, and to the degree statutes are vague, the presence of such differences is guaranteed. One test of maturity of a legal system is its ability to routinely encounter and deal with disputes such as would arise in the above paragraph or the present one, even where basic interests are involved. A difficult form of this problem would likely be if not all parties agree that The Board is the proper body to enforce DOE policies, and therefore, if some parties seek enforcement of DOE policies through the courts in matters where The Board could also have primary jurisdiction. In many jurisdictions, a court receiving such a matte matter to the entity with primary statutory jurisdiction.

A fourth source of emergent properties is likely to be characterized by the parties to a dispute describing each other as "acting in bad faith" (or similar terms) as relates to a particular dispute: for example if one party were to simply ignore the restrictions of a statute, or ignore the mandates of a higher court enforcing a statute or decision. To the degree such behavior occurs, and is not resolvable by transparent means such as described in the above two paragraphs, this poses political issues which would also likely cause the conclusion that a legal and regulatory system were not transparent. Likewise, non transparency exists if the entire process of legal activity depended on the personalities of the present occupants of various offices, rather than on the legal structures which govern those offices. Of course, personality always affects the kinds of professional judgments and form of professional discretion exercised by any holder of public office. A major issue for design of any legal or regulatory system is to permit exercise of necessary discretion while preventing exercise of personal whim that makes "law" a mockery.

VII. APPLICATION TO CONSTITUTIONAL CHANGE IN INDIA

The next example is the co-evolution of legal and economic change in India post-Independence. Ballonoff (1994) argued, with numerous examples and related citations, that changes in the rules that govern the economic system can be a less capital intensive way to develop an economy. The opposite can also occur: poor choice of rules can debilitate an economy as well. At time of Indian independence, 1947, India had one of the most developed economies of the “third world”. Today while the Indian economy has some high spots, it is also among the poorest and least developed. We can measure changes in basic economic policies affecting free choices of individuals by changes made after independence in the Indian Constitution, and changes in related basic economic laws, and associate these changes with changes in economic measures. The two basic measures are the licensing requirements applied to Indian business, and the Constitutional protections for property.

India did not inherit strong licensing requirements form the British. Instead, in 1951, four years after Independence, India passed the *Industries Development and Regulation Act 1951*. The effect of this Act was to require that essentially any business activity required a government license. The effect of that, combined with a broad policy of denial of licenses and nationalization of many industries, was gross reduction in the numbers of and quality of business in India. For example, the numbers of listed airlines (share companies) went from 5 in 1947 to 1 in 1997; the number of insurance companies from 20 to 0; the number of private electricity companies from 35 to 8[88]. The automobile manufactured by the near monopoly company in India has not changed any basic aspect of is design since 1957, itself based on a then already old British design. The increased concentration of industry was not reduced, indeed was enhanced, by the passage of a supposed "antimonopoly" law in 1969, the *Monopolies and Restrictive Trade Practices Act*, whose primary effect was more direct government intervention into the larger of the industries that it may not have already controlled.

Corresponding to increased direct controls, post-Independence the Indian Government was also removing, from its own autonomously written Constitution, any protection for private property as a fundamental right. In the original Constitution, if the Government took private property then compensation (at market values, according to the Courts) was required by the Constitution. In a series of Amendments that even Indian commentators regard cynically, as the Courts continued to find that appropriation required market or fair or reasonable compensation, the Constitution was amended to progressively remove requirements for standards of compensation, to then remove the ability of Courts to question the basis of compensation, and eventually to simply remove the fundamental right to property at all[89].

The realm of restrictive licensing was not curtailed until a partial lifting in 1991 on many but not all industries, and there remains no fundamental protection for property in India. The gross economic measures over this period are revealing. Per capita economic growth was about 3 percent in 1951, but negative in 1991, and was negative for more than half of the intervening years. After 1991 the growth rate has been positive and accelerating. The industrial growth rate in 1951 was about 7.5 percent annually. This fell generally on a secular trend and was even negative in the early 1980's. After 1991 however, and after a readjustment in the 1992-93 period, the rate has been increasing and is higher than at Independence. One can only wonder what the growth rates would be were all restrictive licensing removed, and Constitutional

[88] See *Business India*, August 11 - 24, 1997, page 11.

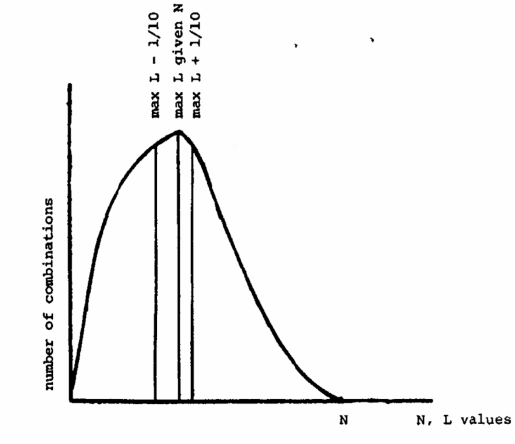
[89] See the Fourth, Seventeenth and Forty-Fourth amendments of the Indian Constitution, as reviewed by Basu, Durga Das, 1996 *Shorter Constitution of India*, 12th Edition, Prentice-Hall of India, New Delhi.pages 869 – 881; and Johari, J. C. 1995 *The Constitution of India: A Politico-Legal Study*. Sterling Publishers, New Delhi.pages 73-76.

protection of a fundamental right for private property re-instituted.

VIII. APPLICATION TO DEMOGRAPHIC CHANGE

The theory of minimal structures rests on a mapping (related to the notion of "descent") which is a surjection. It is well known in combinatorial mathematics that this therefore requires a density function known as the "Stirling Number of the Second Kind" (SNSK) to compute possible distributions that result from acting under that mapping. [90]

This fact allows strong predictions of population measures when only the cultural rules are known. [91] A brief summary is useful here. Let: L = number of "family lines", let N = population size. Then from knowledge of the SNSK density function, of which a stylized typical distribution is given at the left, we can predict a most likely value of L for a given N, and because the density is very compact near L, we can also predict the likelihood of this. In most cases, the density at + or - 10% of the maximum L already drops by a factor of 100 or more from the density of the maximum value of L, and drops rapidly after that. But also, because there is a distribution, we can find some specific growth or population-decline risks associated with that L. (Please note again, that because of the structural theorems from theory of group representations stated earlier, that this is not merely a theory of small sizes; the values thus found are characteristic of the rules, not simply of the minimal size on which the rules can operate.)



If we then let n = average family size, we can easily see that n = N/L for given values of N and L, and also, with approximately equal sex ratio, the number of females (or males) is about ½ N. If we then define the proportion of (socially ascribed) reproducing females = p, therefore p = L/(½ N). This means that n * p = 2, or

$$\tfrac{1}{2}\, n * p = 1.$$

[90] See for example van Lint, J. H. and R.M Wilson 1992 *A Course in Combinatorics*, Cambridge University Press, page 106) or Grimaldi, R. P., 1989 *Discrete and Combinatorial Mathematics*, Addison Wesley, Reading Ma., page 178.

[91] The more detailed development is given in Ballonoff (1976a, 1982a and 1982b). .

Now, because we can write the exponential form $e^{r(t)} = 1$ (the operator "e" used earlier in this summary should not be confused with the exponential form e used in these equations) then we can also derive a general "growth" equation,

$$e^{r(t)} = ½\ n*p.$$

It is noted also below that here r(t) is not the demographer's "capital growth," which is instead denoted here for convenience as R(t); rather r(t) is more like "equity" growth, from which using an analogy to leverage, given below, a prediction of demographer's R(t) can be computed given the structural description and resulting p and n values. By then further deriving

$$e^{r(t)} = ½\ n(t)*p(t)$$

where n(t) and p(t) are the time-dependent average population values of n and p determined (predicted) by the mix of rules at time t, we get an equation that allows prediction of population measures for n(t), p(t), and of the corresponding r(t) and R(t) given the statement only of the cultural rule or mix of rules, and the proportions in which they might be being used or changing in use (if changing).

Use of the SNSK density function allows computation of measurable observations than can be made on a population claimed to be using a particular rule with a particular minimal structure. These measures relate to certain ones also often made using demographic theory, but despite the similar appearance, the measures are not those of ordinary demography. In particular, the well known demographic Leslie matrix[92] finds a growth rate and stable age distribution as eigenvalues and eigenvectors of a matrix of age-structured mortality and fertility or fecundity rates, reflecting the similar approach of Lotka[93] who also stated what is referred to here as the classical form of the "capital" growth version of demography.

But RBS is based on analysis of rules and resulting structures, not of mortality and fecundity. Thus it is necessary to relate "ordinary demographic" concepts to purely ethnographic ones from RBS. The method of achieving this was shown by analogy to the financial concepts of "equity" and "capital," and notion of the "leverage" that can relate equity to capital of an enterprise. Using mathematics developed for financial analysis of financial leverage[94], a link can be computed between the risks of growth or decline of "equity" inherent in

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[92] Leslie , P. H. 1945 "On the use of matrices in population mathematics", *Biometrika* 33: 183-212, and Leslie, P. H. 1948 "Some further notes on the use of matrices in population mathematics", *Biometrika* 35:213 – 245.

[93] Lotka, A 1907, "Relation Between Birth and Death Rates" in *Science* 26(253):435-438.

[94] For a derivation from the work of Lynch, Harry 1971 *Financial Performance of Conglomerates*, Harvard University Press, see Ballonoff 1982a, and for other analogies to microeconomics, see Ballonoff 1987 Chapters 3 and 4.

the RBS SNSK distributions, to the demographic notion of "capital growth." This relationship are given by the equation

$$R(t) = 2\, p(t)\, r(t) / [p(t)^2 + 2r(t)]$$

where R(t) is "capital" growth of a population as understood by standard demography, r(t) is the "equity" growth derived by RBS, and p(t) is the proportion of (culturally ascribed) married and reproducing females.

This in turn leads to computing predicted measures from RBS that can be used to test the theory on actual data. Ballonoff (1982a) demonstrated that RBS successfully predicted the population change experienced in Western Europe for the last 1000 years[95] based on knowledge of the change in cultural structure alone. In Ballonoff 1982b, it was shown that RBS permitted the successful computation of the possible ranges of village sizes for a Kashmiri Pandit population[96] based on knowledge only of the cultural structure; and similarly allowed to successfully predict ranges of values of the Moenkopi Hopi village sizes[97] based on knowledge only of the cultural structure. In Ballonoff (1983), RBS was successfully applied to show that a separation of an Apache village into two new villages was predicted by upper and lower bounds of allowed statistics computed by RBS theory based solely on the knowledge of cultural structure. In Ballonoff (1976a) it was shown that RBS predicts average U.S. population statistics from knowledge of cultural rules of marriage.

In Ballonoff (1998), it was shown that RBS correlates the changes in India's marriage laws with changes in Indian population growth rates. Demographic change in India is one of the more notable phenomena of the modern world. From near zero growth in 1921, the decadal growth rates (growth per ten years) went to about 11 percent in 1931, 14 percent in 1941, 13 percent in 1951 (at about the time of their independence), 22 percent in 1961, 24.5 percent in 1971, 25 percent in 1981 and then down to 23.5 percent in 1991[98]. Over the same period however crude birth rates have fallen steadily from about 48 per thousand in 1921 to about 34 per thousand in 1991[99], a fall of about one-third. Mean age at marriage for males has

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[95] From data described at page 79 in van Bath, B.H. Slicher (1963) *The Agrarian History of Western Europe* London: Edward Arnold

[96] From data described in Madan, T. N. 1965 *Family and Kinship*, Asia Publishing House, Bombay

[97] From data as described in Nagata, S. 1974 *Modern Transformations of Moenkopi Pueblo*, University of Illinois Press, Urbana Illinois

[98] See Shrivastava, O. S., 1994 *Demography and Population Studies*, 2nd Revised Edition, Vikas Publishing House, New Delhi page 367

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[99] Shrivastava, page 344.

risen from about 21 in 1921 to about 24 in 1991[100], while mean age at marriage for females, a more critical measure, rose from about 13 years in 1921 to about 19 years in 1919[101]; this is an increase in generation span of about fifty percent. Such measures alone would lead to prediction that growth rates should be falling, by on the order of thirty to fifty percent. Though at the same period, health was increasing radically so that expectation of life at birth increased between 1921 and 1991 for males from about 27 years to about 57.5 years, and for females from about 27 years to about 59 years; an approximately doubling of life span. These trends appear to be occurring at a uniform rate, continued to the present. Therefore the traditional analysis does not explain either the acceleration of rate of growth nor its incipient decline in rate in the last decade.

Here we demonstrate that while population growth rates in India as a whole are higher than are predicted based on rule bound theory alone (which says only that there are additional causes of growth), the changes in direction of rates, and the consequences of the specific structure of the cultural changes associated with that growth and changes in rates of growth, are consistent with the theory.

It was previously shown that rule bound theory can be successfully used to interpret both large scale and very local demographic changes, both on see for example an application to the demographic history of western Europe over a 1000 year period; populations of native Americans of southwestern United States over only a few decades[102]. The theory has also been shown capable of interpretation of demographic characteristics of India at the local scale, by a description of the village structure of two local villages in northern India [103]

What is needed for the present purpose is a representation of "the" cultural structure of India at large scale, which can lead to a measurable prediction, which in turn can be compared to the available data. While India is culturally diverse, the country is, roughly stated, 88 percent "Hindu" and 12 percent "Muslim". The population statistics available for this study, at least, do not differentiate between the available measures based on this fact. The available data indeed are largely on the presumption that the population studied are either "Hindu" or that the distinction does not matter. In fact, it could matter, and a later study should test this fact based on information which specifically differentiates and describes the "Muslim" populations of India.[104] The

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[100] Shrivastava page 101.

[101] Shrivastava, page 101.

[102] Ballonoff 1982a and 1983.

[103] Ballonoff, 1982 at page 112.

[104] Such data is undoubtedly extant, merely not at present known to this author.

present study is based on the convenience that the entire system can be described as culturally Hindu.

Much is available about presumed ancient or mythological Indian cultures, but the current interest is of modern systems only. Several different sources give a consistent picture. The population is generally divided into fairly small and relatively endogamous (intra-marrying) groups, based on village, caste and kinship designations. The typical size of such units has been described as between about 50 to 300 families.[105] which is generally comparable to the Indian Punjab village size studied previously studied by rule bound theory.[106] . The continuing dominance of caste is verified by several prominent sources.[107] describes similar endogamous structures as "jatis", pages 101 -109; other names for the classifications of the relatively endogamous groups are also known. Endogamy of such groups however is only relative, so for example even Das Gupta [page 87] whose subjects are particularly endogamous locally, found that about 5 % of the marriages within groups he studied were from outside the endogamous group. The fact however that local endogamy is not complete is all that is required to access an important part of the theory of rule bound systems as applied to cultures, the so-called "amplification" equation of [Ballonoff 1982 a, equation 17] for measurement of per-generation population growth due to cultural change; this in turn also enables the use of data from [Ballonoff 1982 a] as cited below.

While there remains in India a preference for choices of partner within the "caste" or inherited political grouping, other rules govern choice by exclusion of possible partners based on degree of kinship relationship. In fact, rules of kinship exclusion are a pervasive part of local community life. So much so, that this has been embodied into India law, in the form of the *Hindu Marriage Act, 1955*. The Act proscribes a marriage between any two persons who are "sapindas" of each other, which is to say if the two people are related by the third generation or closer via the maternal line or the fifth generation or closer via the paternal line.[108]. [see Act at sections 3 (e) and (f) especially]. The Act also explicitly prohibits marriage among what western systems would call first cousins or closer relatives [see Act section 3 (g) (iv)] and some other inter-generational marriages. The choice of setting sapinda prohibitions at 3 and 5 generations however was a compromise, as some local groups had stronger prohibitions, and others lesser. Thus the Act also says that a

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[105] Kapadia, K. M., 1966 *Marriage and Family in India*, 3rd. Edition, Oxford University Press, Calcutta , page 118.

[106] Ballonoff, 1982 a..

[107] Das Gupta, Sata dal, 1986 *Caste Kinship and Community, System of a Bengal Caste*, Universities Press (India) Ltd., Hyderabad, pages 4, 36, 87; Kapadia, Chapter 6; Mandelbaum, David P, 1970 *Society in India* 1970 University of California Press, Berkeley, 1972 Indian Edition.

[108] Such data is undoubtedly extant, merely not at present known to this author.

Hindu marriage is permissible if "the parties are not sapinds of each other, unless the custom or usage governing each of them permits of a marriage between the two" [Act section 5(v)].

The practical effect of the law is therefore to permit individual free will to reign, within the cultural systems and otherwise practical limits available. Thus Kapadia page 130 has described the real marriage patterns allowed by this law thus:

> "According to the Act, then, marriage between two persons related within five generations on the father's side and three on the mother's is void unless permitted by local custom. ... In view of the fact that the family circle, in modern days, is generally a limit of three generations, the limit, if any limit is ever needed, should be three generations only. As a matter of fact, in these days when the individual choice of partner in marriage is recognized as necessary and desirable even by the older generation, any artificial shackles in the form of exogamous restrictions are outmoded."

Kapadia collects additional evidence from the post-Independence era, such as by student surveys, that such individual choice is in fact being exercised, largely preserving traditional systems but with less restrictions of this type. In fact, even the *Hindu Marriage Act* reflected a reduction from a much higher degree of sapinda prohibition, such as prohibition six or seven degrees on the fathers side. (This paper avoids analysis of ancient systems which may have allowed much closer relationships either generally or for specific cultural sub-groups; the study covers only the modern and largely post-independence period).

We can thus conclude that post-Independence India (after 1947, with the Act in question dated from 1955) has seen a path of structural change in its rules of marriage, from those with more extensive kin-based restrictions, to lesser restrictions. While culturally quite different from the change in western Europe from the lineage exclusions systems of about 1000 a.d., the qualitative path of change is similar to that which led to the more "modern" and less restrictive systems that dominate today. Therefore the computed prediction of structural change on demographic effects are quantitatively similar, except much faster. The Indian system is shifting from one with a higher structural number to one with lower number. The theory of Ballonoff[109], computed that this results in a path of increasing growth followed by a decline in growth which occurs after the system has more than half completed the transition.[110] Except for the speed of change the actual computations presented in that earlier paper are also a reasonable proxy for estimating the changes in India. The peak per generation growth rate shown by that Table 4 are about 10 percent per generation, using a

[109] 1982 a, Table 4

[110] In fact, for a completely different reason that described by Pearl and Reed in their classic paper "Logistic Curve Theory of Population Growth", this transition would also predict a logistic shaped growth path, cumulating quickly as the underlying transition completes, but only after a period of high growth shortly before that culmination.

generation interval of about 25 years; the data summarized above on India imply a generation interval of between about 15 years. Thus, the decadal growth rate implied by the Table 4 analysis of Ballonoff (1982a) would be a bit less than 10 percent per decade. This accounts for about a third of the observed growth in India. But the rate of growth in Table 4 would also be declining as the system approaches more predominant use of the newly established cultural system. Thus, growth shown by that table is declining, as is also the case in Indian empirical growth.

IX. ANALYSIS OF UNIQUE SYSTEMS

The reason one can identify a particular culture as being *that* particular culture, is that each culture is unique. This has often led researchers in the past to conclude that therefore culture can not be analyzed at all, except perhaps as a literary object. The theory of rule-bound systems, as laid out in references instead shows that while each culture may be unique, that does not prevent analysis. Instead, the rules systems of the culture are subject to analysis, similar to that common from other areas of research[111]

Previously for example it was pointed out that the rule structure of a cultural system resembles the rule structure of a class of computer program called the operating system, and therefore that the technical subject called temporal logic of concurrent operating systems was also a theory of human rule-bound systems[112]

Rule-bound systems can be related to classical automata theory. This can likely be most easily seen by comparisons of rule-bound theory to the work on the mathematics of "structural programmability" of biologically evolving systems, such as developed by Conrad (1983, 1988).. In biological organisms, the "rules" of the organism are embodied, at least in part, in the genes of the organisms. In general, the less complex is the organism, the greater is the degree of its activity which is directly programmed genetically. Complex multicellular organisms which also have brain systems (such as humans) are more able to choose actions.

Conrad analyzed these issues by defining three notions of programmability. The first of these states that "A program in the strict sense is a rule that (when embodied) generates the behavior of a system, subject

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[111] Such as in Conrad, Michael (1983): *Adaptability, the Significance of Variability from Molecule to Ecosystem*, Plenum Press; Conrad, Michael (1988) "The Price of Programmability", page 285 - 307 in R. Herken (ed.) *The Universal Turing Machine*, Oxford University Press; Ezhkova, Irina V (1992).: "Contextual Technology for Supporting Decision Making", pages 508 - 509, in R. Trappl, Ed. *Cybernetics and Systems Research, '92*, Volume 1, World Scientific; Manna, Zohar and Amir Pnueli (1992) *The Temporal Logic of Reactive and Concurrent Systems*, Springer-Verlag

[112] Ballonoff, 1994, and Manna and Pnueli (1992).

to the condition that the rule is of a finite type"[113]. The analogy could not be more plain. Also note that all rules previously discussed by the theory of rule-bound systems are certainly finite.

Next Conrad defined "effective programmability", as "A real system is (effectively) programmable if it is possible to communicate desired programs to it in an exact manner (without approximation) using a finite set of primitive operations and symbols"[114]. Superficially, this definition is also met by human rule-bound systems, since all systems discussed in Ballonoff (1987, 1994) are actual human systems which use languages to communicate rules. The definition is strictly met by the human marriage rule systems described mathematically by various authors, cited in Ballonoff 1994). The definition is somewhat less clearly met when we consider that while human languages do, at any moment, probably use a "finite set of primitive operations and symbols", such languages are not considered to always communicate "in an exact manner (without approximation)", although certainly most legal system at least seek to do this.

Finally Conrad also defines that "A physical system is structurally programmable if it is effectively programmable and if its program is mapped by its structure"[115]. On first sight, this definition seems to preclude all human cultural systems, since they are not "physical". But that would be a false inference: humans are indeed physical, and their relations with each other are indeed real. The essential problem with deciding if human rule systems are structurally programmable is deciding whether "its program is mapped by its structure".

The possibly surprising answer is that, in at least some cases, this is almost certainly so, while in at least some others, the human system as well as its environment form the physical structure used for mapping the rules. If one does not believe this, consider the example of riddles. Riddles are analogies using natural experience or relationships among humans to pose and solve cognitive problems. Riddles are not rules, as such, but their existence in their common form using natural objects and relationships as analogies[116] proves the existence of cognitive structures which meet the criteria for structural programmability. The idea that human cultures can and do map their cultural rules through analogies to relationships among natural objects, animals, and humans, was explored in very great depth in many well known works by the social anthropologist Claude Levi-Strauss. The similar notion that human cultures use human body parts and their interconnections

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[113] Conrad 1988, at page 287.

[114] Conrad 1988, at page 287-288.

[115] Conrad 1988, at page 288.

[116] Robert Austerlitz, "Ob-Urgic Metrics", Vol. No. 174 in *Folklore Fellows Communications*, Helsinki, Finland 1958.

and functions as analogies for cultural structure has been developed by Mary Douglas[117].

While cultural studies are often seen as trivial compared to "hard sciences" because of their subject matter, the above citations and conclusion show that the opposite is the case. Cultural systems are in fact physical systems, or, at least are structurally programmable in certain important ways. This being the case, it should also be possible to reach conclusions about structurally programmable systems which also apply to human rule systems. This is also true, and indeed examples of this were used and cited in Ballonoff 1994.

To realize such analogies are possible, consider a brief summary of the properties of systems analyzed by Conrad: "a computing system cannot at the same time have high programmability, high computational efficiency, and high evolutionary adaptability" [4, at page 285]. Human rule systems which attempt to map all actions of each individual by defined rules tend to fail (as witnessed by various recently demised totalitarian states), or to survive only where their physical environments were also very stable for very long time periods (such as in pre-Western contact Australian aboriginal cultures). Only where the system of rules permits more flexibility do the same sets of rules tend to survive as the physical or technological environment changes.

This description of how a culture operates is very similar to Ezhkova's mathematical framework for a self-teaching artificially intelligent machine which uses its own experience to construct analogical rules of interpretation[118]. Human cultures construct themselves in much the same way: use of experience to create patterns for prediction. The above references show how this is done in at least some human systems based on naturally occurring relations as the basis for the analogies. Indeed, Ezhkova gives an example of how a particular control device was constructed using her methods. The device measured internal temperatures and conditions of a physical system and represented this to the system operator by using images of an ocean in various states and colors.

The importance of these various observations to viewing human cultural rules as part of classical systems theory can not be overstated. The papers by Conrad cited here show how structurally programmable systems are Turing machines. This conclusion alone is sufficient to show that study of rule-bound systems is properly part of the subject matter of systems analysis. Thus other conclusions by Conrad about properties of biological evolution, or by Ezhkova, or Manna and Pneuli, about logics of operating systems, can also be usefully studied for parallel results in description of human rule-bound systems.

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[117] Mary Douglas, *Natural Symbols*, Pantheon Books, 1982.

[118] Ezhkova 1992

X. INFORMATION THEORY OF RULE BOUND SYSTEMS

Amiel Feinstein[119] [1958] outlined the essential problem of information theory as follows:

"Of the difficulties which confront us when we attempt to construct a quantitative theory in which the concepts "production of information" and "transmission of information" are meaningful, two stand out at once. First, we must construct a mathematical model in which we can speak of information being produced and transmitted. Second we must assign a quantitative measure to the amount of information involved. At first glance, it might appear that the solution to the second problem would follow directly from the first. . this is actually not the case ... ."[120]

The traditional development of information theory is then motivated as follows:

"Intuitively, we would agree that we receive information whenever we are informed of an even whose occurrence was previously not certain. Furthermore, it is reasonable that, within certain limits, at least, the more likely an event is, the less information is conveyed us by the knowledge of its actual occurrence. Ignoring for the moment this last remark, we can already introduce a certain amount of formalism into the discussion. Let x represent the occurrence of an event ... [and] ... Let Ix denote the amount of information conveyed to us by the knowledge of the occurrence of x."[121] .

Traditional information theory is thus derived by defining a set of mutually exclusive events, and defining the information content I of each event in terms of the probability of occurrence of the event. The measure of information over the entire system is then found as a function H of the probability weighted information of all of those events. About this fact, Feinstein noted "This is actually a very strong condition; in fact ... it practically suffices to determine the form of H ... without regard for the definition of H in terms of I"[122] . He then demonstrates the fundamental theorem of information theory, which is "The maximum information content of a source having n elements is log n, and is achieved only when all elements have equal probability".[123],

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[119] Feinstein, Amiel 1958 *Foundations of Information Theory* McGraw Hill.

[120] Feinstein, 1958, at 2.

[121] Feinstein, 1958, at 2.

[122] Feinstein, 1958, at 4.

[123] Feinstein at page 15, Theorem 1.

This concise summary is sufficient to show where things went astray in applying this theory to rigorous study of cultural systems seeking self reproduction, for which the most relevant information is occurrence of an event in which the system reproduces. If there is any non-zero probability of an event in which survival does not occur (that is, in which reproduction of a system capable of following the rule does not occur) then the relevant information is reduced by the existence of this probability. In Feinstein's words, we precisely can not "ignore the last remark" which traditional theory does in fact ignore.

We can now show why information theory resembles thermodynamics, and then in turn why neither thermodynamics nor information theory, as interpreted traditionally, is isomorphic to rule bound theory. As just summarized above, the reason information theory finds that the maximum information is produced when all events are equiprobable is that it implicitly weights information as being the deviation of the system from "randomness" defined as equiprobability of all possible events. Now consider the underlying combinatorial density function of thermodynamics. Thermodynamics requires distributions based on the Stirling Number of the First Kind -- which is to say that thermodynamics assumes all particles of a system are identical to each other (such as that all the molecules of air in a room are similar) but that all locations into which they may be put are different (the spatial distribution of air in the room is important). It then turns out that of the possible ways in which air can be distributed in a room, that which has the highest probability (largest possibility density) is the one in which air is distributed evenly throughout all of the space in the room. This is the same as saying that the probability that of the event "an air molecule is in this part of the room over here" is identical for all parts of the room to which one might point.[124]. . This in turn results in the first theorem of information theory, that the information is maximum when all events are equiprobable. From this formal identity, based essentially on "ignoring the last remark" of Mr. Feinstein, general systems theory infers the universality of both thermodynamics and information theory, and then applies the formal structure of both to problems of cultural science.

This is why one of the more interesting results of rule bound theory is that it turns out to require use of a very different underlying combinatorial density function for the counting properties of populations following a rule, than required for the density functions of statistics of systems studied by traditional theory. [125] The reasoning is that because the underlying mathematics that relates populations to cultural configurations is a surjection, then statistics based on the Stirling Number of the Second Kind are required for rule systems.

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[124] See van Lint, J. H. and R. M. Wilson 1992 *A Course in Combinatorics* Cambridge University Press, at page 472-473 for the relationship of the Stirling Number of the First Kind to the counting of identical objects into non-identical cells.

[125] Ballonoff 1987, Appendix II.

This is also mathematically identical to saying that at a critical point, rule bound theory requires computing a possibility density function based on the distribution of non-identical objects into identical "locations"[126].

These however are the opposite assumptions from thermodynamics: it would be as if assuming that all atoms are unique, and all locations in the room are non-distinguishable. This hardly makes sense as a description of the physical system. But in cultural rule theory, the underlying mathematics are the mappings of unique individuals onto graphs showing actual and possible relationships among identical roles, and also the mappings from possible graphs of social structure in one generation to the possible graphs in the next. Unique individuals fill identical roles; the graphs are possible configurations of those roles. It is critical for the system to survive with the same culture that a configuration be reproduced which is capable of (1) permitting the functions of the culture to occur given the existence of that particular graph in that generation; and (2) in turn also allows successive generations of configurations to occur, each of which permits the operations of the culture to occur in its own generation. While all roles of a given type may be identical, not all configurations of roles permit reproduction to continue to occur according to the rules; therefore, not all possible distributions of unique individuals into a given number of identical roles will permit the system to survive.[127]

We can now construct an information theory of rule bound systems. Define an event as the occurrence of a particular configuration of role relationships. Define the information content of a particular event as the product of whether a particular configuration permits the system to survive (1 if yes, 0 if no), times the relative probability that the rule permits the given graph to form (out of all possible graphs allowed by the rule in a population of a given size). This information is maximized over the whole set of possible events when the rules maximize the creation of configurations of role structures that can survive and reproduce (hence permit continued existence of the same rules), and minimize the probability of creation of graphs which can not do these things. The practical meaning of the statement that cultural theory uses surjections is that an algebraic map representing graph formation under a rule, from possible configurations in one time period to those possible under a viable rule in the next, does not permit the formation of all theoretically describable possible configurations, or maps among such configurations between generations. Under the most viable rules, those configurations which will not permit the rules to continue to reproduce will also not be formed at all, or will be formed with lower probability. This means that the average information content (weighted average probability of system survival) of those configurations which are allowed to be produced is higher under what we clearly

[126] This reasoning is similar to that commonly found in standard books on combinatorics such as van Lint and Wilson 1992 at page 106 and Grimaldi, Ralph P.(1989) *Discrete and Combinatorial Mathematics* Addison Wesley at page 178 for the relationship of surjections and counting functions to the Stirling Number of the Second Kind.

[127] This is a verbal interpretation of the theory found in Appendix I to Ballonoff, 1987.

regard as the more viable rules.[128] Therefore also, we can construct an information theory that is consistent with rule theory -- in fact, I just did it verbally.

But this version of information theory is not identical to thermodynamics. In particular, it does not contain the vaunted First Theorem, that information is maximized by the equiprobability of all possible events! That this is true is already apparent from the definition of information used above. In the rule bound version of a "First Theorem" we need instead a limit formulation which states something quite different: as the population size approaches (from above) the size of the minimal structure which permit the rules to survive, then the information is maximized for those rules which cause a greater proportion of all possible configurations to be isomorphic to the minimal configuration. That this is true follows from the definition of a minimal structure (minimal configuration) as the smallest which permits the rule to operate in a given generation and to survive and reproduce an isomorphic structure in the shortest possible number of generations. (All known minimal structures for marriage rules reproduce isomorphic images in one generation).

The presence of minimal structures also leads to another important information theoretic result about cultural systems: they are efficient processors of classificatory information. This follows from the isomorphism of this aspect of rule bound systems theory to parallel processor design theory. Ballonoff (1994, 1995 and 1996) argued that cultural theory is analogous to the mathematical theory of temporal logic of concurrent operating systems. An important object in the concurrent parallel operating systems is a design called "butterfly architectures"[129]. Butterfly architectures are among the class of algorithm-structured architectures, applied in the design of massively parallel processor systems to reach efficient sorting, fast Fourier transform information processing, and to permit simplified programming which permits program statements to self-order with least complexity. Ballonoff (1996) showed that butterfly architectures are isomorphic to minimal structures of marriage systems.

Butterfly architectures are also similar to structurally programmable systems, in that the networks generated in a butterfly architecture mirror the structure of the algorithm used to generate the structure[130]. It is

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[128] For example, rules that produce 1-stable configurations in their minimal structures as defined in Ballonoff 1987 Appendix I have very high information content by this measure -- in fact in a system which can reproduce exactly the minimal structure in configuration each generation , the information content is 1; meaning that survival is assured.

[129] E. V. Krishnamurthy. 1989 *Parallel Processing, Principles and Practice.* Addison Wesley, especially at pages 230 - 237.

[130] E. V. Krishnamurthy. 1989 especially at pages 234.

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also known in parallel processing from the same source that the best results are obtained when the program and the machine graphs are isomorphic, which is also a property of a structurally programmable machine. Ballonoff[131] argued that cultural systems are structurally programmable. Structural programmability is another way of saying that the behavior or experience of the system is used to map the rules and predict future behavior. Cultures therefore act like a self-teaching machine which uses its own experience for creating analogies that become the rules system of the culture. As noted especially by Ezhkova[132] these are systems which create rules based on their experience and then communicate by analogy (a features both also expressed by "structural programmability"). In parallel processors, the greater the similarity of the rule systems (cultural systems), that is, the greater the degree of their isomorphism, the lower the cost of communications within the system. Thus, the human systems are also *efficiently* self-organizing, as demonstrated by the result that their structures are efficient for similar purposes in parallel processor design.

The adaptability of the rules systems and their ability to change in efficient ways also determines the survivability of the system, as explored in much greater depth in Part XI for bio-evolution of cognition. This was argued for cultural rules[133] and for the co-evolution of cultural rules with biological environments[134] in (Durham, 1991). Butterfly architectures occur in both processor design and in natural human systems due to information processing efficiency of the resulting networks, in both cases. In the cultural systems, part of the efficiency is in "naturally adaptive self-learning systems".

Finally, note that because butterfly architectures are also representations of fast Fourier transforms, which are examples of mathematics highly dependent on mathematical groups, this lends support to the "group axiom" mentioned in Part I.E. that human systems of rules are representable as mathematical groups of operators.

XI. RBS AND BIOLOGICAL EVOLUTION OF COGNITION

Biological evolution is the process of natural selection for genetic properties which enable behavior that enhances survivability and reproduction of individual members of a species, in particular environments. Species are populations of interacting individuals. When sub-populations of a species are completely

[131] See Ballonoff 1995.

[132] See Ezhkova 2002, 2004.

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[133] Ballonoff 1994

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[134] William H. Durham, 1991, *Coevolution: Genes, Culture and Human Diversity.* Stanford University Press.

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reproductively isolated from each other they may tend to evolve into separate species. Most species however live within local populations which are only relatively endogenous, and thus have biological exchange among the sub-populations. This happens even in fairly small populations, and indeed even in humans where such phenomena may be recognized as including migration, adoption or even as "cheating" on the cultural rules. The property that sub-populations are not entirely endogenous enhances the spread of genetic characteristics among the sub-populations of the species, while minimizing or insuring against risks of local demographic failure that may affect relatively smaller or more isolated populations. This feature may therefore be called "amplification" of local survivability, or, by analogy to borrowing of capital in the world of finance, "leverage".

The theory of rule bound systems begins with analysis of the cultural rules and behavior of populations, as affects reproduction of the population. The theory recognized the effect on local viability due to exchanges of individuals among sub-populations, by adopting an equation from the financial theory of leveraged transactions. The resulting equation, there called the amplification equation, was published in [Ballonoff, 1982a] eqn. (17), reproduced in Part VIII above.

Rule bound systems theory however is not only a theory of human cultures. Ballonoff[135] demonstrated that the amplification equation also predicts conditions under which human cultures differ from the "cultures" of social insects. In particular, the amplification equation, together with other properties of RBS, predict as follows: (i) within a dynamic biochemical environment, for a species whose individuals use internal biochemical means of control, natural selection will favor evolution of a second means of internal control -- such as a nervous system. While essentially all species have individuals that use internal biochemical communication, not all have individuals with well developed secondary (nervous) systems; (ii) once this second system exists, its' symbolic capabilities facilitate both self-awareness by individuals and also inter-individual communication; (iii) species such as social insects which use pherhormonal communication and rely upon high degrees of individual genetic similarity for that communication, have social systems with very different measures under the mathematical theory of culture than do human cultures; (iv) when the population risks of growth or failure are measured by the amplification or leverage equation the social systems of humans and social insects fall at opposite extremes of the value of one of the two key variables of that equation namely, the value of p(t) of proportion of population engaged in reproduction; (v) however, at both extreme values of p(t), the stability of the population (risk of population decline or reproductive failure) are smaller, while at values in between the risks are much higher; (vi) in the intermediate ranges of p(t) values few social systems with such measured values are observed; (vii) the "plasticity" of human cultural or social systems is much greater than that of social insects, corresponding both to the fact that humans exist in much more diverse environments, and can change their cultural systems thus adapting far more easily;

[135] Ballonoff 1987 Chapter 5

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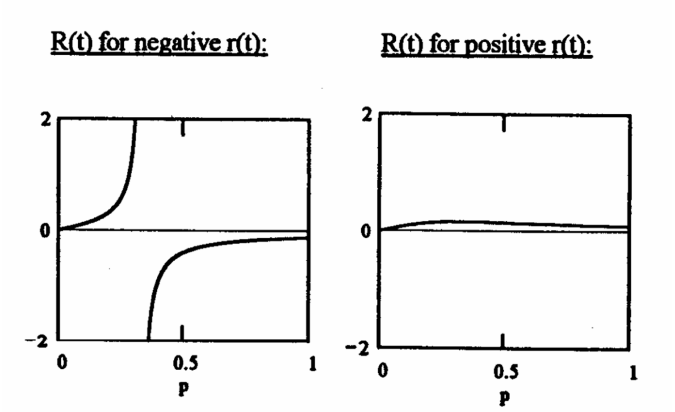
In summary, humans rely on their "secondary" neurological symbolizing capacity, whereas social insects rely much more on genetically inherited biochemical means of communication, and these results correspond to the presence of two relatively more stable regions measured by the amplification equation[136]. One region of relative stability occurs at high values of p(t), which is to say, where a high proportion of the population engages in cultural marriage and biological mating, as is typical of human cultures and mammalian social systems generally. The other region of relative stability occurs at very low values of p(t), which is to say, where a small proportion of the population engages in reproduction, whether socially or biologically, as is the case for social insects.

These results can be further explained by the fact that the amplification equation contains a singularity[137]. Due to the asymmetry of population growth and decline risks above and below this singularity, species with social or cultural systems whose p(t) measures fall above the singularity are much more likely to have increasingly capable symbolic means of inter-individual communication using the "secondary" internal communication systems of individuals. Species whose social systems have p(t) values which fall beneath the singularity are much less likely to have characteristics of self-awareness or symbolic communication. Systems below the singularity however may have much more stable "cultural" systems — as witnessed by the fact that species of social insects have existed for many more millions of years than mammals, in apparently very similar condition to those social insects which exist today, whereas the biology and social systems of mammals, and certainly the cultural systems of humans, evolve much more rapidly.



The singularity is illustrated in the graphs left of R(t) for p(t) from 0 to 1.0. The first graph shows R(t) for positive values of r(t), while the graph on the left shows R(t) for the negative value r(t) = -.055, which is approximately where the singularity becomes apparent in the table. It is quite apparent that any species whose social system permit them to exist in the graph on the left faces a very high risk of being drawn to catastrophic extinction, possibly following a population explosion.

[136] Note also that humans are a single species which exists over diverse environments, whereas social insects, while existing in diverse environments, are not a single species.

[137] Ballonoff 2000b.

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However, if the social system can exist in the graph on the right, then the system will have a much better chance of survival, at much more moderate growth rates.

Thus, a population acting near the singularity (approaching it from below, that is expanding its population moving from the left toward the center of one of these diagrams) might be highly rewarded (as increased viability) for increasing in that direction, until it reaches or perhaps crosses the singularity. At that point, it faces extreme risk of rapid extinction. Should it survive that period, then there is further inducement to move rapidly away from the singularity, by increasing the p(t) such as by adoption of social or cultural systems that induce this result. More dispassionately stated, populations which can increase p(t) most quickly are the least likely to incur the high risk of extinction (high negative R(t)) near the singularity.

Combining the above result with the previous results of [Ballonoff, 1987] Chapter 5 the singularity in the amplification equation has important implications for understanding the evolution of species with self-aware individuals. Simply stated, species below the singularity are much more likely to have little inter-individual communication, and that which exists governed predominantly by biochemical means. Such forms of communication would tend to be slow to evolve and also very stable, which is also to say, inflexible. Such species would be much less likely to evolve self-awareness, or if so to require much larger time spans of evolution. However species above the singularity have the opposite of these properties: self-aware interacting individuals whose communications include more symbolic and flexible means.

Thus, if within a species consisting of individuals whose communications and control systems are biochemically (hormone) controlled, there evolve individuals with a secondary non-hormonal internal communications and control system, then the more dynamic the changes in the external chemical and biochemical environment, the greater will be the selective pressures favoring further evolution and enhancement of the secondary internal communication and control system. This was established in [Ballonoff, 1987] Chapter 5 as a property favoring selection in the direction of higher p(t) values; the present result shows an additional strong mechanism driving natural selection in the same direction. Because this secondary control system is much more likely to be capable of symbolic representation (the primary internal communications and control systems being bio-mechanical, not symbolic) then evolution of the ability for flexible inter-individual communications systems are also more highly favored in such environments.

Natural selection obviously implies evolution of self-conscious individuals might be favored, but it is much more highly favored in species whose social systems fall above the singularity, and thus much more likely to be present in them, and with a much higher level of capability. The process of natural selection means that species whose social systems fall above the singularity will have individuals with secondary internal control systems that are capable of symbolic representation, hence also of inter-species

communications by non-hormonal means. Such species will also be capable of much more plastic communications hence of survival in more physically diverse environments. For example, humans, whose cultures permit them very plastic control of their p(t) values, are among the most environmentally dispersed of any single species.

The above also implies that species with secondary internal communication and control systems capable of inter-individual symbolic communications, that are in turn capable of affecting the reproductive strategies ("cultures" or social systems) of the species, will be highly favored by evolutionary processes, once the species produces a social system above the singularity. Indeed, if the secondary systems do not affect inter-individual symbolic control systems that affect reproduction, then the species is probably not above the singularity at all.

Notice that systems composed of self-conscious and symboling individuals may come to act within symbolic systems (cultures), of whose properties not all of the individuals may be conscious. Indeed, it may be that none of the individuals are conscious of the effects of the resulting cultural or social system. However, the selective advantages that may accrue to individuals who are also conscious of the properties of the cultural system is also apparent. This is therefore an emergent property of the above noted processes of natural selection. Indeed, the capacity for inter-individual communication by symbolic means is itself an emergent property of the process of natural selection resulting in the existence of the "secondary" non-bio-mechanical means of internal individual self-control to correct for errors of the endocrine system, as described in [Ballonoff, 1987] Chapter 5.

Biological evolution has not stopped in modern human societies. Because the modern environment is even more chemically diverse than the natural environment (by adding to the variety of the natural environment), then similar and perhaps more intense evolutionary pressures of the same sort continue to exist, favoring increasingly capable secondary systems that can over-ride increasingly hostile or at least increasingly diverse biochemical environments. Modern human environments therefore induce natural selection that intensely favors individuals with increased capabilities of the secondary internal communications and control system. Thus should have as a by-product, populations of increasingly self-aware individuals. Such individuals would include some whose self-awareness includes greater awareness of properties of the system of symbols. Thus the human world of increasingly complex symbolic systems of communications and control external to individual members of that species (i.e. entertainment, politics, law, etc.) is simply an extension of these same processes of natural evolution.

TABLE 1
POWERS AND DUTIES OF ERB

"TO ACHIEVE MORE COHERENT POLICY FORMULATION ... CONSOLIDATE AND ENTRUST IN ONE BODY ALL THE REGULATORY AND ADJUDICATORY FUNCTIONS COVERING THE ENERGY SECTOR" (EO 172 PREAMBLE)

PRIVATE[138] ELECTRIC ENERGY COMPANY RATES (CA 146, EO 172)

PRIVATE ELECTRIC ENERGY COMPANY CERTIFICATES OF PUBLIC CONVENIENCE (CA 146, PD 1206, OPINION 98)

COOPERATIVE RATES (RA 7638, PD 269 SEC. 16(O) CHAPTER II)

NPC RATES (RA 7638, RA 6395 SEC. 4)

NOTICE, HEARING, PROCEDURE AND RELATED POWERS (CA 146, ETC)

138 "Private" used here to mean any non-government company organized as other than a cooperative.

TABLE 2
POWERS AND DUTIES OF DOE

(ALL REFERENCES TO RA 7638)

POLICY OF THE STATE: CONTINUOUS AND ADEQUATE SUPPLY OF ENERGY, ULTIMATELY THROUGH SELF RELIANCE, USE OF INDIGENOUS RESOURCES, EFFICIENT USE OF ENERGY
(SEC. 2 (A), MADE PURPOSE OF DOE BY SEC. 4)

POLICY OF THE STATE: INTEGRATE AND COORDINATE
(SEC. 2 (B), MADE PURPOSE OF DOE BY SEC. 4)

POWERS AND FUNCTIONS OF DOE (SEC. 5)
(A) FORMULATE POLICIES FOR EFFICIENT SUPPLY, ECONOMIC USE
** (A) PROVIDE A MECHANISM TO RATIONALIZE AND INTEGRATE

(B) DEVELOP ENERGY PROGRAM ANNUALLY (INCLUDING PRIVATIZATION AND COMPETITIVE OBJECTIVES)

(C) PROGRAMS FOR ...

(D) SUPERVISE GOVERNMENT ACTIVITIES

** (E) REGULATE PRIVATE SECTOR ACTIVITIES UNDER EXISTING LAW

(F) ... (J) DO VARIOUS THINGS IN FOUR YEARS

** (K) FORMULATE SUCH RULES AND REGULATIONS AS MAY BE NECESSARY TO IMPLEMENT THIS ACT

** (L) OTHER IMPLIED NECESSARY POWERS

TABLE 3
DUTIES OF DOE BUREAUS

(ALL REFERENCES TO RA 7638, SECTION 12)

	CITATION	BUREAU	DUTY
VERB:			
DEVELOP AND IMPLEMENT			
	12(B)(3)	EUMB	NEW TECHNOLOGIES
	12(B)(6)	EUMB	MIDDLE AND LONG TERM ENERGY TECHNOLOGY STRATEGIES
	12(B)(10)	EUMB	ENERGY CONSERVATION PROGRAMS
	12(B)(2)	EPMB	DATA AND INFORMATION PROGRAM
ASSIST			
	12(A)(1)	ERDB	FORMULATE AND IMPLEMENT PLANS FOR LOCAL SUPPLY OF ENERGY
	12(A)(2)	ERDB	LOCAL RESOURCE PLANS
	12(A)(5)	ERDM	FORMULATION OF POLICIES FOR SERVICE PROVIDERS
	12(B)(1)	EUMB	POLICIES FOR ENERGY SECTOR PRODUCTION, TRANSMISSION AND DISTRIBUTION
	12(B)(4)	EUMB	RURAL ENERGY DEVELOPMENT
	12(B)(5) AND SEC. 25	EUMB	POLICY FOR ALLOCATION IN CRITICAL LOW SUPPLY
**	12(C)(1)	EIAB	REGULATORY POLICIES FOR RESOURCE SUPPLY ACTIVITIES
**	12(C)(3)	EIAB	FINANCIAL AND FISCAL POLICIES FOR ENERGY SUPPLY COMPANIES
	12(D)(1)	EPMB	INTEGRATED SHORT, MEDIUM AND LONG TERM PLANS
CONDUCT			
	12(A)(3)	ERDB	RESEARCH ON LOCAL RESOURCES
	12(D)(6)	EPMB	STUDIES ON INTERNATIONAL ISSUES
ASSURE			
	12(D)(5)	EPMB	INCORPORATION OF ENVIRONMENTAL POLICIES
PROVIDE			
	12(A)(4)	ERDB	CONSULTATIVE TRAINING AND ADVICE TO REGULATORY INSTITUTIONS
	12(B)(6)	EUMB	INFORMATION ON ENERGY TECHNOLOGY

TABLE 3
DUTIES OF DOE BUREAUS (CONTINUED)

(ALL REFERENCES TO RA 7638, SECTION 12)

VERB:	CITATION	BUREAU	DUTY
REQUIRE	12(B)(9)	EUMB	COLLECTION OF WASTE OIL
REVIEW	12(D)(4)	EPMB	PATTERNS OF ENERGY CONSUMPTION
SUPERVISE, COORDINATE AND INTEGRATE	12(D)(3)	EPMB	PLANS FOR ENERGY SUPPLY DEVELOPMENT
MONITOR	12(B)(2)	EUMB	ENERGY SECTOR CONSUMPTION
	12(B)(7)	EUMB	ENVIRONMENTAL STANDARDS OF DENR
RECOMMEND	12(B)(8)	EUMB	WAYS TO RESOLVE CITING ISSUES
DRAW-UP	12(C)(2)	EIAB	PLANS FOR SUPPLY DISRUPTIONS

TABLE 4
HOW THE AGENCIES DIFFER

ERB	DOE
QUASI-JUDICIAL PROCESSES (CA 146)	CODE PROCESSES (AT MOST)
HAS POWER OF SUBPOENA (CA 146)	HAS NO SUCH POWER
ACTS BY VOTE BASED ON FORMAL EVIDENCE (CA 146)	ADMINISTRATIVE DECISIONS USING AUTHORITY OF EXECUTIVE
ACT USING ONLY FORMAL RULES PROCESSES (CA 146)	FORM OF ACTION NOT DEFINED BUT HAS POWER TO ISSUE RULES AND REGULATIONS NECESSARY TO ITS DUTIES (RA 7638)
ALL PROCEDURES DETERMINED BY CA 146 AND CODE	ELECTRIC PROCEDURES (WEAKLY) DETERMINED BY THE CODE; (PETROLEUM POWERS SET BY RA 6173, PD 1206, PD 1573)
HAS DIRECT JURISDICTION OVER PARTICULAR ENTITIES INCLUDING ENFORCEMENT (RA 146, PD 1206, EO 172)	NO DIRECT JURISDICTION, MAY HAVE IMPLIED JURISDICTION OVER PERSONS AND CORPORATIONS
INVESTIGATE ANY PUBLIC SERVICE MATTER ON OWN MOTION (CA 146)	INVESTIGATE ONLY SPECIFIED OR IMPLIED MATTERS (RA 7638)
NO DIRECT JURISDICTION OVER IPP'S (OPINION 95 OF 1988)	DIRECT IPP JURISDICTION (RA 7638, BOT LAW, EO 215)