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Understanding the Complex Timing Effects Of Public Policy Interventions in Industry Clusters

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Time Structures

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Abstract

Built-in asynchronies between political process and regulated sectors or activities can produce unintended disruptions in rates of economic change and development undermining the original intent of the policy or regulatory action. Such events sometimes lead to unexpected future disruptions as well. A policy approach is needed that adaptively ties the right mix of resources and regulatory activity to the timing of particular stages of economic development or growth associated with a particular industry.

These public policy timing problems are explored using the concepts of "time-ecology", "heterocrony", and "temporal signature. The full range of linear and nonlinear time/space web linkages (electronic, selling and buy, technology transfer are examples) in an government/industry cluster between political, economic, and other elements creates an interconnected ecology—a time-ecology—of unique, more or less intense, and often complex rhythmic pulses that occur in parallel with each other and connected with each other across multiple time scales flowing into the future. Each organizational structure is situated in the past, present, and future in a unique way (time signature). Linkages mutually influence structuration by varying their rate of development and growth (heterochrony). Nonlinear dynamics may be involved in these interactions. This whole process occurs on linked government/industry adaptive landscapes. The paper ends with suggestions for testing the theory.

Key words: Industry clusters, public policy, time-ecology, heterochrony, temporal signature.

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of Public Policy Interventions in Industry Clusters[1]

Governance And Industry Clusters

Historically, mixed state economic development policy results have led analysts to call for a whole new approach to economic development, emphasizing regional economies and industry clusters (see for example: Buss, 1999; DRI/Mcgraw-Hill, 1996; Eisinger, 1995; Fosler, 1990; Koehler, 1994; Meyer and Hassig, 1993; Murray, 1999; Rey and Matheis, 1999; Ross and Friedman, 1990; and Waits, Kaballey, and Hefferson, 1992). But, there is only modest agreement on how state government public policy and regulatory activity should be structured (see for example: Agranoff and McGuire, 1998; Anderson 1994; Cogley and Schaan, 1994; Doeringa, Terklas, Topakakian, 1987; Humphrey, Ericson, and McCloskey, 1989; Ledebur and Barnes, 1993; Malecki, 1990; Pilcher, 1991; Rondinelli and Vastag, 1997; Porter, 1998; Tabb, 1984; and Waits, 1996). Research reports mixed results on whether public policy and regulatory activities have an impact on economic development either directly through regulations, taxes, subsidies, and public infrastructure, or indirectly through environmental and other quality of life activities (Ambrosius, 1988; Brace, 1991; Grant and Wallace, 1994; Immergluck, 1993; Kresl, 1994; Lowery and Gray, 1992 and 1995; and Rosentraub and Przybylski, 1996). Even when such state policy innovations are made in response to economic crises, the controversy continues on how much they contribute to economic development in the absence of such economic crises (Bartik, 1996; Bingham and Bowen, 1994; Coughlin and Cartwright, 1987; Gold, 1995; Goss and Phillips, 1999; Hays, 1996; Leicht and Jenkins, 1994; Nice, 1994; Webster, Mathis, and Zech, 1990; and Wetstein, 1996). These varying results emphasize the point that what the timing, type, parallel implementation requirements across a region or cluster, and flow of state and regional public resources and regulatory activity should be over some future period to support or hinder a business cluster's ability to achieve competitive advantage, is not well understood even though the literature reviewed above and other research suggests that varying and integrated combinations of such resources are important at different developmental stages (Elkins, Bingham, and Bowen, 1996; and Kaufman, et. al., 1994).
The catch is that the nonlinear nature of economics and politics during development transitions, such as those associated with California' s emerging new information economy, are complex, sensitive to initial conditions, with both elements interacting across time in unknown ways (Rosser, 1999).

Government/Industry Clusters As Time-Ecologies

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The complex parallel activities and feed back relationships of business and services components, government and competitive market variations produce and continuously organize the evolution of an industry cluster. The organization of these processes go through varying stages, have varying permutations of new or old institutional relationships, and are strikingly different depending on industry, culture, history, and political system (McIntyre, 1996). The full range of linear and nonlinear time/space web linkages (electronic, selling and buy, technology transfer are examples) in an government/industry cluster between political, economic, and other elements creates an interconnected ecology—a time-ecology—of unique, more or less intense, and often complex rhythmic pulses that occur in parallel with each other and connected with each other across multiple time scales flowing into the future (Adam, 1990, 1994; Bateson, 1980; Koehler, 2000; Koehler-Jones, 1996; Kummerer, 1998; and Young, 1988).

A time-ecology incorporates the specific spatial and temporal dimensions that a government/industry cluster is embed in (Kummerer, 1998). The spatial dimension includes both geographic extensions and sequential morphogenic-like, rule driven parallel timed processes for each of these elements producing hierarchies of evolving developmental and growing forms that "flow" into each other in certain ways (for varying approaches to morphogenic processes, including economic ones, see for example: Thom, 1972; Abraham, 1985; Kaufman, 1993; Goodwin, 1994; Holland, 1995; and De Landa, 1997). Flows reveal themselves, in a metaphorical sense, as a multitude of continuously emerging structures such as spheres (firms and agencies), sheets (regulatory authority) and tubes (network connections) that interrelated in various ways such as binaries (firm to government program), radiant centers (small firm to prime contractor), and layers (regional economic supports to firm) for example (Volk, 1995). The temporal dimension times all of this out.

Time-Ecology and Heterochrony

The concept of “heterochrony” can be effectively used to describe the overall ordering and regulation of a time-ecology’s developmental and growth process producing varying flow structures. Heterochrony, as applied in biology, involves decoupling of the three fundamental elements of growth—size, development, and time—leading to variation in a descendant’s ontogeny compared to its ancestor’s as each factor varies relative to the other. The "normal" pattern of development for an organism is an elaborate and complex, multifaceted but ordered cascade of events where different body parts assume different shapes and grow at different rates over the course of development. Equally important, the timing of reproduction, fecundity, and longevity are all adaptations in same that morphological changes are (Gould, 1977, and McKinney and McNamara, 1990). For the most part, biological heterochronic changes do not affect the entire organism but only an aspect of an organ system or body part. Edeleman, an embryologist, defines heterochrony as “alterations of tissues and form by mutations leading to changes in the relative rates of development of different body parts…which…explains the emergence of different body plans” (Edeleman, 1988). These factors suggest that morphological advantage alone is not enough; the timing of reproduction, the size and number of individuals, and other adaptive shifts in the timing of growth and development must also be considered.

These concepts are important for understanding a government/industry cluster time ecology because it could be that the interpenetration of flows, acting as a heterocrony, can coevolve and influence the rate of growth and developmental stage of its various structures. (For an interesting biological experimental demonstration of this process, see Blackstone, 1997). Government interventions may be quite selective as to which portion of the firm they influence tending to create different rates of growth, and/or development resulting in different observed firm shapes and feeding back, different government policy and governmental organizational shapes. Such interventions can geographically extended like a plane, corresponding to a jurisdiction.

For biological systems, changes in the timing of development or growth may be environmentally induced and constitute a significant adaptive mechanism. This later point suggests that there may be a spectrum of organic form variations, a "morphospace," that forms an adaptive landscape (McGhee, 1999). This in turn suggests that heterochronic effects can be mapped onto an adaptive landscape, creating a useful way to view and perhaps assess the interactive result of various political interventions on an industry cluster.

Gould's "r and K" theory provides a way to map both government and an industry cluster adaptive landscapes. "In brief, r and K theory tries to establish which environmental conditions would favor maximization of r (the intrinsic rate of natural increase [of an organization in our case] and which would lead to the maximization of K (the carrying capacity of the environment [and market]; both parameters can not be maximized at the same time." (Gould, 1977, 291). Those conditions that favor r selection include large, frequent, and unpredictable environmental fluctuations, frequent catastrophic mortality, superabundant resources and lack of crowding relative to resource availability. Biologically speaking, early reproduction and an abundance of offspring by relatively small parents would be adaptive. With respect to industry, this suggests the proposition that new and emerging markets, or technologies, that are not well defined such as the Internet, multi-media, and biotechnology might be populated by a large number of small start-up firms maximizing r (Figure 1). For example, small firms are more likely to explore technologically diverse and uncrowded territories (position A on the landscape in Figure 1), leaving the domination of more mature technologies to larger firms (Almeida and Kogut, 1997).

(Figure 1 about here)

Situations favoring K selection included crowded, stable and benign environments. This suggests a mature, well-established market dominated by a few large firms (B in Figure 1). In both r and K selection, we can see that the processes of heterocrony involving maturation and growth of firm size are more fundamental than their results. This could be an important clarification of Kauffman's work on adaptive landscapes (Kauffman, 1995). He tends to focus almost exclusively on morphology, mutating random alleles associated with an entire genome to arrive at a fitter organism that is able to climb higher on a fitness peak. Kauffman has critized heterocrony in past as being useful for comparing patterns but not for explaining change (Kaufman, 1983). More recent research shows that both heterocrony and morphology are required for an adequate understanding of morphogenesis and ontongeny (McKinney and McNamara, 1990).

It would appear that heterochrony describes the variety of rates of development and growth rates which determine how various information, material, interpretative and other elements create a firm or government structure. A more generalized application suggests that changing the heterochronic causal relationships among an aggregate's parts as they emerge changes the time pattern of the flows of energy, information or resources within or between parts of the associated government/industry cluster time-ecology. This also suggests that changing the rhythm, pace and connectivity of flows can modify this aggregate as well. Practically, this might mean that a firm must consider the number of competitive configurations that its flow permits contextually within the heterochronic demands of its environment. It also suggests such a selection may be directly or inadvertently influenced by government regulatory or programmatic decisions. Both activities may feed back and forth to each other, varying each's fitness relative to their adaptive landscapes.

A time-ecology of networked flows could continuously give rise, through appropriately or inappropriately timed interactions and multiplier and recycling effects between flows, to a complex and often emergent aggregate structure that could not be predicted from its parts. Small changes to a component in this larger aggregate structure could affect rates of flow, feeding forward or back, varying the entire time-ecology' s heterochronistic pattern and the resulting overall form (that of the industry cluster for example). Turbulence across the cluster or in various layers (that of networked firms for example) might even result in the inefficient use of energy, resources or information, a major problem for hyper-competitive emerging industry clusters (Organization Science, 1996).

Recycling and Multiplier effects suggest that, depending on the timing of particular actions as noted above, the parallel interaction between industry clusters elements or with government in the space/time of a time-ecology could be quite complex exhibiting a number of linear and nonlinear characteristics as they evolve (Rosser, 1999). Interactions within and between individual organizations hint at the possibilities (for an excellent overview see: Anderson, Meyer, Eisenhardt, Carley, and Pettigrew, 1999.) This suggests that political and legal interventions are likely to change heterochronically linked causal relationships, affecting not only a part of the time ecology and its *Eigenzeiten* but also the *kairos* and *chronos* of the entire time-ecology (Adam, 1993; Brown, 1994; Kaufman, 1993, 1995; Koehler, 1999; Kummerer, 1996; Rummel, 1972; and Rutz, 1993). Chaotic and complex behaviors resulting from public policy decisions have already been suggested and their potential influence on government or industry identified (Kiel, 1994, and Elliot and Kiel, 1999).

Heterocrony and the Temporal Signature

Up to this point there has been little to distinguish our borrowed physical or biological processes from the public policy time-ecology we are interested in. The concept of "temporal signature" helps bridge this gap. The temporal signature is a theoretical construct that describes the organizing structure of the complex timings born of individual internal experience and expectation (Koehler-Jones, 1996). Groups can construct a new temporal signature as they interact with one another, producing and structuring a common flow. The temporal signature is not taxonomy of time but an emergent pattern of time-related components characterizing the flow of an individual's or organization's time identity or time personality. Each element of a time-ecology has a characteristic temporal signature. A temporal-signature influences functioning by creating a posture and a disposition toward action that combines past orientation with future expectations. It can be used to explain behaviors by describing characteristic ways of thinking about and feeling about, and acting and reacting to time.

The components of the temporal signature are: depth, density, reality, focus, tempo, duration, rhythm, and awareness (Koehler-Jones, 1996). These components are organized into two interacting sets: the temporal perspective and the temporal progression. Each component of the two sets has both objective and subjective aspects, the values of which can be highly variable even within specific contexts. None are more fundamental than another, with each partially taking their value from interacting with the others. These values may be volatile, changing rapidly with respect to another component's value. Collectively, they determine the temporal signature's continuously emergent structure. The temporal signature is the unique organizing principle behind an entity' s temporal posture as it flows into the future.

As noted, a temporal signature is a set of emergent patterned relations among the components of temporal perspective and temporal progression. The components of temporal perspective are: depth, density, reality, and focus. "Depth" characterizes meaningful past or future horizons. Historic and future horizons may be located anywhere along a continuum stretching from very close to the present to distances beyond the lifetime of the entity. Part of the investigation of depth concerns future horizon predictability (clear, complicated, or complex) and memory of the past. "Density" is a measure of the number of events planned, currently experienced or remembered. It can refer to the happening or occurrence of an emotional, cognitive, or behavioral event. "Reality" represents an assessment of likelihood of outcome and fidelity of memory. In addition to objective measures, elements underlying "reality" include attitudes toward control, risk, fatalism and self-determination. Deeper variables can include intuition, imagination, magical thinking and nostalgia. "Focus" is a measure of the relative importance of the past, present and future. It asks which of these modalities is most salient or where awareness is concentrated.

Temporal progression is composed of tempo, duration, rhythm and awareness. "Tempo" refers to the *continuum* of speeds running from fast including slow to being stopped. "Duration" is *continuance* in time. It' s the length of time that a state or event continues or lasts. "Rhythm" is the pattern made when tempo changes after some duration. It describes accelerations and decelerations. Rhythm involves clear demarcations created by social events and time-keeping techniques. Richer information about rhythms comes from studying the subtle shifts within and between activities. For example, polychronic activity (synchronic loading) produces a kind of rhythm caused by doing multiple things "at once" or by moving quickly between various activities.

"Awareness" refers to consciousness of tempo and duration, usually with respect to accomplishing a task or living through a process or event.

Time-Ecology Dynamics

Fluid dynamics may provide helpful hints for understanding how flows, with thier characteristic temporal signatures, are interpenetrated by complex heterochronic extensions from other flows. (For a discussion of turbulence and economics see De Landa, 1997; Louca, 1997; and Ruelle, 1991. For applications of chaos theory to government activity see: Brown, 1994; Campbell and Mayer-Kress, 1997; Elliott and Kiel, 1999; and Rubin and Hilton, 1996). First, we learn from physics that mixing is not stirring. Stirring combines flows but produces no fundamental change in either. In contrast, mixing of two or more initially segmented flows results in a reaction, release of energy, or some other change that produces a new flow or state where the identities of the combining flows are changed or even lost. Our analysis of heterochronically driven interactions in a time ecology would seem to be a form of mixing in that particular elements are influenced by their environment to develop or grow at a different rate. A more formal definition of mixing with hints about how it might apply here is: "…The operation by which a system evolves from one state of simplicity (the initial segregation ([of flows]) to another state of simplicity (the complete uniformity [of the new flow]). Between these two extremes, complex [temporal signature and heterochronic] patterns emerge and die. Questions then naturally arise: how can the geometry of complex patterns be characterized, what is the clock, the time-scale of the process, and what are the structures involved in the flow?" (Villermaux, Chate, and Chomaz, 1999, p.2). We have theorized on how a time-ecology's varying time-scales and temporal signatures may change developmental or growth processes producing differing structures.
Many scales might be involved in a particular interaction, much like the way certain diseases develop and spread (Philippe, 2000), or only a few.

In the physical and biological sciences the rate and form of interaction between two flows varies, displaying many geometries (Villermaux, Chate, and Chomaz, 1999, and Farge and Guyon, 1999). These patterns may point to useful ways of conceptualizing and visualizing mixing and stirring of flows in a time-ecology. For example, the interaction might be very rapid, occurring in a thin layer at a small scale close to the interface (interpersonal or machine) or the interaction may occur more slowly between detached blobs (work groups) and the flow they are emersed in (industry cluster/government). Defussion may also occur where components of one flow are dispersed in another but little change occurs across scales. For example, the interactions in plasmas, gases, liquids, between particles or rocks, or among cultural artifacts, ideas or information (memes), etc. could produce varying emergent geometries. Interactions at or between various scales may be fractal, a folding, perhaps stirring, cutting across multiple organizational scales such as the way leukemia may cluster in cities (Phillippe, 1999) or the fractal structure of cities (Makse, Havlin, and Stanley, 1995).

Folding, unlike mixing, does not lead to homogeneity. But it is one way to produce fractals that extend across scales. Slow mixing might involve pinching off blobs of ideas, artifacts, resources, information, and body language, such as the activities of a work group in a larger organization, that only later defuse via mixing into the entire organization. The physics of flows suggests that knowing how flow interfaces are distorted, flow wall stresses, and how rapidly an event occurs can provide interesting information about how quickly such interactions could give rise through heterocliny to new developmental and growth processes producing new structures.

In the end, what we are looking for is a satisfactory way to describe and account for the parallel, distributed histories and the possible futures of the cumulated stretchings, vortexes, cascades, sedimentation, stirrings, and other processes that we suspect are characteristic of the heterochronic interactions between various flows, at different scales in a time-ecology as they move through different regimes including turbulence (for descriptions of the possibilities see: Abraham, Gardini and Mira, 1997; Abraham and Shaw, 1988; De Landa, 1997; and Favre, Guitton, Guitton, Lichnerowicz, and Wolff, 1988). Dynamical systems theory distinguishes between five main types of temporal patterns that, if found, may help to describe the various temporal signatures, time-ecology heterochronies, flow timings, interpenetration, and intensity at and across various scales. For organizations, these are fixed (static), periodic (cyclical), chaotic (strange), colored noise (pink, brown, or black), or random chance (Dooley and Van de Ven, 1999).

Time-Ecology Simulation

An adequate simulation (adaptive agent, dynamic, or some combination) of a government/industry time ecology might include a geographical time and space distribution of firm types, say a prime contractor, small manufacturers, and their suppliers. Each is defined by their stage of development, temporal-signature, resource and technology requirements, age and size, geographic location relative to other firms, their present internal past-future temporal perception, their foresight horizon, variations in connectivity (Internet or not), and adaptive strategy. They are embedded in an industry cluster that itself reflects a certain stage of development, may be globally extended, and has a particular foresight horizon. Both are supported by regional economic resources that are also changing. This complex structure interfaces with government. Government regulatory structures and programs are differentiated by their unique temporal signatures, and by geographic jurisdiction and resource allocation. Government is structured in a different way than an industry cluster, being hierarchical, relatively predictable, linear in its clock-time, and bounded by constitutional, statutory, political and ideological constraints. Linkages between levels of government—such as the Governor’s policy, funding streams and the provision of direct services—are complex involving multiple timings, lags, etc. Government regulations, program inputs and expenditures are induced using heterochronically to selected firms or geographic areas, either speeding up or slowing down their temporal signatures, and their stages of development or growth. This in turn feeds back to government agencies via political processes associated with the agency, the Legislature and Governor. The whole public policy time-ecology is located on co-evolving adaptive landscapes; one for government and one for the cluster.

Ideally a time-ecology simulation reveals the multiple forms of time associated with each flow extended across a geographic space collectively organized by the ecology' s heterochronic developmental and growth processes. Examples of varying individual timings that influence political action are: (1) *Eigenzeiten* or the embedded times specific to an organism or system that must be considered to influence that flow's development; (2) *kairos*, being the right time for action to cause a desired effect, and (3) *chronos* which refers to the timing of events and their duration, and sequence, as well as the intensity that (trans)actions are conducted at. Government policy relevant questions might include: What is the effect on the patterned relationships among the elements of the time ecology? Does it produce multiplier, recycling, or other effects as it propagates across government, across industry or across both? Over what time period does it increase competitive advantage, if at all? Is one combination of interventions better than another relative to firm age, size, developmental stage, rate of growth, etc.? How about in terms of timing and delays? Are there better structural ways of tying the two pieces together that would smooth unwanted velocity problems? In terms of the cluster's evolution, can we qualitatively and quantitatively describe how the continuous interactive structuring of time by government interventions at various scales produces bifurcations or emergence at the edge of chaos? What is needed to produce adaptive policies that evolve to address changing conditions, yet serve their original purpose?

References Cited

Abraham, Ralph (1985). On Morphodynamics. Santa Cruz, CA: Aerial Press.

Abraham, R., & Shaw, C. (1988), Dynamics the Geometry of Behavior: Part Four: Bifurcation Behavior. Santa Cruz: Ariel Press.

Abraham R., Gardini, L., & Mira, C. (1997). Chaos in Discrete Dynamical Systems, New York: Telos.

Adam, Barbara (1990). Time and Social Theory. Cambridge: Polity Press, 1990.

Adam, Barbara (1993). Time and Environmental Crisis: An Exploration with Special Reference to Pollution. Innovation, Vol. 6, no. 4.

Adam, Barbara (1994). Environment and Ecology, in Samuel Macey (Ed) (1994). Encyclopedia of Time. New York: Garland Publishing, Inc.

Agranoff, Robert, and Michael McGuire (1998). The Intergovernmental Context of Local Economic Development. State and Local Government Review, Vol. 30, No. 3, Fall.

Almeida, Paul, and Bruce Kogut (1997). "The Exploration of Technological Diversity and the Geographic Localization of Innovation." Small Business Econmics, 9 (1), 21-31.

Ambrosius, Margery (1988). The Effectiveness of State Economic Development Policies: A Time-Series Analysis. *Western Political Quarterly*.

Anderson, Gary (1994). Industry Clustering for Economic Development. Economic Development Review, Spring.

Anderson, Philip, Alan Meyer, Kathleen Eisenhardt, Kathleen Carley, and Andrew Pettigrew (1999). Introduction to the Special Issue: Applications of Complexity Theory to Organizational Science. Organization Science, Vol. 10, No. 3, May-June.

Bartik, Timothy (1996). Growing State Economies: How Taxes and Public Services Affect Private-Sector Performances. Economic Policy Institute.

Bateson, Gregory (1980). Mind and Nature: A Necessary Unity. Glasgow: Fontana.

Bingham, Richard and William Bowen (1994). The Performance of State Economic Development Programs: An Impact Evaluation. Policy Studies Journal, Vol. 22, No. 3.

Blackstone, Neil (1997). Dose-Response Relationships for Experimental Heterochrony in a Cologial Hydroid. The Biological Bulletin, Vol. 193, No. 1.

Brace, Paul (1991). The Changing Context of State Political Economy. Journal of Politics, Vol. 53, No. 2.

Brown, Courtney (1994). Politics and the Environment: Nonlinear Instabilities Dominate. American Political Science Review, Vol. 88, no 2, June.

Brown, Shanon and Kathleen Eisenhardt (1998). Competing on the Edge: Strategy as Structured Chaos. Boston, Mass.: Harvard Business School Press.

Buss, Terry (1999). The Case Against Targeted Industry Strategies. Economic

Development Quarterly, Vol. 13, No. 4, November.

Campbell, David and Gottfried Mayer-Kress (1997), "Chaos and Politics: Applications of Nonlinear Dynamics to Socio-Political Issues," in Celso Grebogi and Jame Yorke (1997), The Impact of Chaos on Science and Society. New York: United Nations University Press.

Cogley, Timothy and Desiree Schaan (1994). Should the Central Bank be Responsible for Regional Stabilization? FRBSF Weekly Letter, No. 94-25, July 15.

Coughlin, Cletus and Phillip Cartwright (1987). An Examination of State Foreign Export Promotion and Manufacturing Exports. Journal of Regional Science, Vol. 27, No. 3.

De Landa, Manuel (1997). A Thousand Years of Nonlinear History. New York: Swerve.

Doeringa, P., D. Terklas, G. Topakakian (1987). Invisible Factors in Local Economic Development. New York: Oxford University Press, 1987.

Dooley, Kevin and Andrew Van de Ven (1998). "A Primer on Diagnosing Dynamic Organizational Processes,"Kevin.Dooley@asu.edu Kevin.Dooley@asu.edu

DRI/Mcgraw-Hill (1996). America's Clusters: Experiences and Lessons Learned. Washington, D.C.: U.S. Dept. of Commerce, August 1996.

Eisinger, Peter (1995). State Economic Development in the 1990s: Politics and Policy Learning. Economic Development Quarterly, Vol. 9, No. 2, May.

Elliott, Euel and L. Douglas Kiel (1999). Nonlinear Dynamics, Complexity and Public Policy. New York: Nova Science Publishers, Inc.

Elkins, David, Richard Bingham, and William Bowen (1996). Patterns in State Economic Development Policy: Programmatically Rich and Programmatically Lean Policy Patterns. State and Local Government Review, Vol. 28, No. 3, Fall.

Farge, Mark and Etienne Guyon (1999). "A Philosophical and Historical Journey through Mixing and Fully-Developed Turbulence," in Chate, et.al., Mixing: Chaos and Turbulence, New York: Kluwer Academic/Plenum Publishers, 11.

Fosler, R. Scott (1990). State Strategies for Business Assistance, in J. Schmandt and R. Wilson (1990). Growth Policy in the Age of High Technology. Mass: Unwin Hyman, Inc.

Gold, Steven (Ed.) (1995). The Fiscal Crisis of States: Lessons for the Future. Washington D.C.: Georgetown University Press, 1995.

Goodwin, Brian (1994). How the Leopard Changed Its Spots: The Evolution of Complexity. New York: Touchstone.

Goss, Ernest, and Joseph Phillips (1999). Do Business Tax Incentives Contribute to a Divergence in Economic Growth? Economic Development Quarterly, Vol. 13, No. 3, August.

Gould, Stephen (1977). Ontogeny and Phylogeny. Cambridge, Mass.: Belknap Press of Harvard Press.

Grant, Don and Michael Wallace (1994). The Political Economy of Manufacturing Growth and Decline across the American States, 1970-1985. Social Forces, Vol. 73, No. 1, September.

Hays, Scott (1996). The States and Policy Innovation Research: Lessons from the Past and Directions for the Future. Policy Studies Journal, Vol. 24, No. 2.

Holland, John (1995). Hidden Order: How Adaptation Builds Complexity. New York: Helix Books.

Humphrey, Craig, Rodney Erickson, Richard McCluskey (1989). Industrial Development Groups, External Connections, and Job Generation in Local Communities. Economic Development Quarterly, Vol. 3, no. 1, February.

Immergluck, Daniel (1993). The Role of Public Infrastructure in Urban Economic Development. Economic Development Quarterly, Vol. 7, No. 3.

Kaufman, Allen, Ross Gittell, Michael Merenda, William Naumes, and Craig Wood (1994). Porter's Model for Geographic Competitive Advantage: The Case of New Hampshire. Economic Development Quarterly, Vol. 8, No. 1, February.

Kauffman, Stuart (1983). "Developmental Constraints: Internal Factors in Evolution," in B. C. Goodwin, N. Holder, and CC.Wylie (eds). Development and Evolution. Cambridge: Cambridge Press.

Kauffman, Stuart (1993). The Origins of Order. New York: Oxford University Press.

Kauffman, Stuart (1995). At Home in the Universe. New York: Oxford University Press.

Kiel, Douglas (1994). Managing Chaos and Complexity in Government. New York: Jossey Bass.

.

Koehler, Gus, (1994). New Challenges to California State Government's Economic Development Engine. Sacramento: California Research Bureau.

Koehler, Gus (1999). "Political Regulation of Time-Ecologies," a paper presented at the Ninth Annual Society for Chaos Theory in Psychology and the Life Sciences, June 23-26, 1999, University of California, Berkeley. Being revised for reconsideration in Nonlinear Dynamics, Psychology and the Life Science.

Koehler, Gus (2000). The Time Compact Globe and the High-Tech Primitive at the Millennium, in Elliott and Kiel, Nonlinear Dynamics, Complexity and Public Policy. New York: Nova Science Publishers, 2000.

Koehler-Jones, Victoria (1996). The Use of Temporal Constructs as a Model for Understanding Perception of Environmental Hazard. Dissertation, Department of Sociology, University of Nevada, Las Vegas, August.

Kresl, Peter (1994). The Determinants of Urban Competitiveness: A Survey, in Peter Kresl and Gappert, Gary (Eds.)(1994). North American Cities and the Global Economy. Urban Affairs Annual Review, 44.

Kummerer, Klaus (1996). The Ecological Impact of Time. Time and Society, Vol. 5, no. 2.

Leicht, Kevin and J. Jenkins (1994). Three Strategies of State Economic Development: Entrepreneurial, Industrial Recruitment, and Deregulation Policies in the American States. Economic Development Quarterly, Vol. 8, No. 3, August.

Louca, Francisco (1997). Turbulence in Economics. Lyme, New Hampshire: Edward Elgar Publishing.

Lowery, David, and Virginia Gray (1992). Holding Back the Tide of Bad Economic Times: The Compensatory Impact of State Industry Policy. Social Science Quarterly, Vol. 73, No. 3, September 1992.

Lowery, David and Virginia Gray (1995). The Compensatory Impact of State Industrial Policy: An Empirical Assessment of Midterm Effects. Social Science Quarterly, Vol. 76, No. 2, June.

Ledbur, Larry and William Barnes (1993). All in it Together: Cities, Suburbs and Local Economic Regions. National League of Cities, February.

Makse, Harnan, Shlomo Havlin, and H. Eugene Stanley (1995). "Modelling Urban Growth Patterns," Nature, 377, no. 19 (October 1995), 608-612.

Malecki, Edward (1990). Technological Innovation and Paths to Regional Economic Growth, in J. Schmandt and R. Wilson (1990). Growth Policy in an Age of High Technology. Mass: Unwin Hyman, Inc.

McGhee, George R. (1999). Theoretical Morphology : the Concept and its Applications. New York : Columbia University Press.

McIntyre, R. (1996). Regional Variations on Russian Chaos: Price control, regional trade barriers, and other abominations. Communist and Post-Communist Studies, 29.

McKinney, M.L. and K. J. McNamara (1990). Heterochrony: The Evolution of Ontogeny. New York: Plenum Press.

Meyer, Geroganna and John Hassig (1993). Economic Development Policy. State Tax Notes, November 22.

Murray, Edward (1999). Cluster-Based Development Strategies: Lessons from the Plastics Industry in North Central Massachusetts. Economic Development Quarterly, Vol. 13, No. 3, August.

Nice, David (1994). Policy Innovation in State Government. Ames, IA: Iowa State University Press.

"Hypercompetition," Organizational Science, Special Issue, 7, no. 3 and 4, May-June, July-August.

Phillippe, Pierre. (1999). "The Scale-Invariant Spatial Clustering of Leukemia in San Francisco", Journal of Theoretical Biology, preprint.

Philippe, Pierre (2000). "Epidemiology and Self-Organized Critical Systems: An Analysis in Waiting Times and Disease Heterogeneity," Nonlinear Dynamics, Psychology and Life Sciences, 4 (2), p. 275.

Pilcher, Dan (1991). The Thrid Wave of Economic Development. State Legislatures, November.

Porter, Michael (1998). Clusters and the New Economics of Competition. Harvard Business Review, November-December.

Rees, John (1986). Technology, Region and Policy. New Jersey: Rowan and Littlefield.

Rey, Sergio, and Daniel Mattheis (1999). Identifying Regional Industrial Clusters in California: Volume I: Conceptual Design. Sacramento: California Employment Development Department, August.

Rondinelli, Dennis and Gyula Vastag (1997). Analyzing the International Competitiveness of Metropolitan Areas: The MICAM Model. Economic Development Quarterly, Vol. 11, No. 4, November.

Rosser, J. (1991). From Catastrophe to Chaos: A General Theory of Economic Discontinuities. Boston: Kluwer Academic Publishers.

Ross, Doug and Robert Friedman (1996). The Emerging Third Wave: New Economic Development Strategies. Entrepreneurial Economy Review, Autumn.

Rosentraub, Mark and Michael Przybylski (1996). Competitive Advantage, Economic Development, and the Effective Use of Local Public Dollars. Economic Development Quarterly, Vol. 10, No. 4, November 1996.

Ruelle, David. Chance and Chaos (1991) Princeton Science Library.

Rummel, R. (1972). Social Time and International Relations. General Systems, 17.

Rubin, Barry and Mark Hilton (1996), “Indentifying the Local Economic Development Impacts of Global Climate Change,” Economic Development Quarterly, 10, no. 3, August 1996, 262-279.

Rutz, Henry (1993). The Politics of Time. American Anthropological Association, American Ethnological Society, Monograph Series, no. 4.

Schiller, Dan (1999). Digital Capitalism. Cambridge, Mass.: MIT Press.

Slavin, Matthew and Sy Adler (1996). Legislative Constraints on Gubernatorial Capacity for State Industrial Policy: Evidence from Oregon's Regional Strategies Program. Economic Development Quarterly, Vol. 10, No. 3, August.

Tabb, William (1984). Urban Development and Regional Restructuring, an Overview, in L. Sawers and W. Tabb (1984). Sunbelt/Snowbelt. New York: Oxford Press.

Thom, Rene (1972). Structural Stability and Morphogenesis: An Outline of a General Theory of Models. New York: Addison-Wesley Publishing Company, Inc.

Villermaux, Emmanuel, Hugues Chate, and Jean-Marc Chomaz, “Why Mixing?” in Chate, et.al., (Eds.) Mixing: Chaos and Turbulence, New York: Kluwer Academic/Plenum Publishers, 1999. P. 2.

Tyler Volk (1995). Metapatterns: Across Space, Time and Mind. New York: Columbia University Press.

Waits, Mary, Karol Kaballey, and Rick Heffernon (1992). Organizing for Economic Development: New Realities for New Rules. Public Administration Review, Vol. 52, No. 6, November/December.

Waits, Mary (1996). Economic Development Strategies in the American States, in Kuotsai Liou (Ed)(1998). Handbook of Economic Development. New York: Marcel Dekker, Inc.

Webster, Elaine, Edward Mathis, and Charles Zech (1990). The Case for State-Level Export Promotion Assistance: A Comparison of Foreign and Domestic Export Employment Multipliers. Economic Development Quarterly, Vol. 4, No. 3, August.

Wetstein, Matthew (1996). Abortion Rates in the United States. Albany: State University of New York Press.

Young, Michael (1998). The Metronomic Society. Cambridge: Harvard University Press.

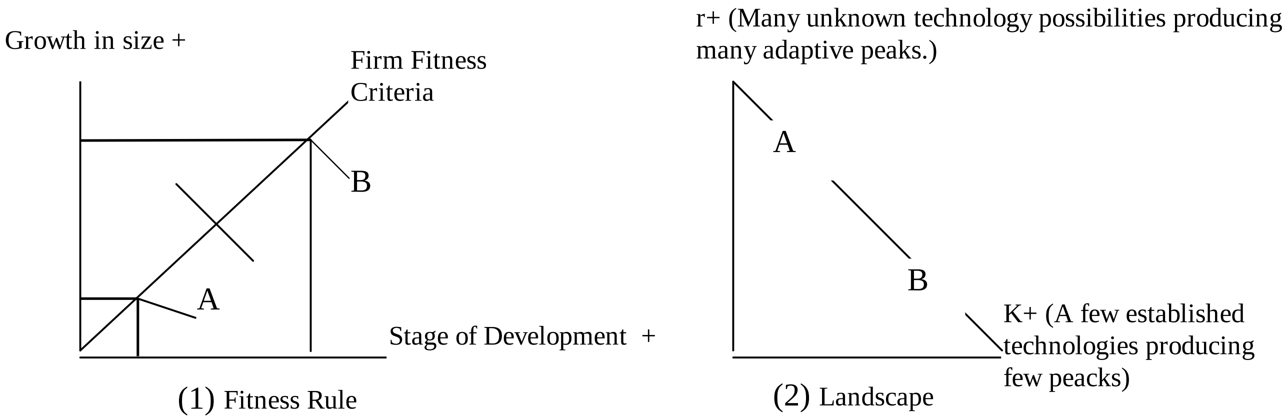

Figure 1: Theoretical Heterochrony Firm Fitness Rule (1), Applied to a Technology Innovation Landscape (2).