

Forstater, Mathew

Working Paper

Visions and scenarios: Heilbroner's worldly philosophy, Lowe's political economics, and the methodology of ecological economics

Working Paper, No. 413

Provided in Cooperation with:

Levy Economics Institute of Bard College

Suggested Citation: Forstater, Mathew (2004) : Visions and scenarios: Heilbroner's worldly philosophy, Lowe's political economics, and the methodology of ecological economics, Working Paper, No. 413, Levy Economics Institute of Bard College, Annandale-on-Hudson, NY

This Version is available at:

<https://hdl.handle.net/10419/31589>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.



Working Paper No. 413

**Visions and Scenarios: Heilbroner's Worldly
Philosophy, Lowe's Political Economics, and the
Methodology of Ecological Economics**

by

Mathew Forstater,
The Levy Economics Institute of Bard College
University of Missouri–Kansas City
forstaterm@umkc.edu

October 2004

The Levy Economics Institute Working Paper Collection presents research in progress by Levy Institute scholars and conference participants. The purpose of the series is to disseminate ideas to and elicit comments from academics and professionals.

The Levy Economics Institute of Bard College, founded in 1986, is a nonprofit, nonpartisan, independently funded research organization devoted to public service. Through scholarship and economic research it generates viable, effective public policy responses to important economic problems that profoundly affect the quality of life in the United States and abroad.

The Levy Economics Institute
P.O. Box 5000
Annandale-on-Hudson, NY 12504-5000
<http://www.levy.org>

Copyright © The Levy Economics Institute 2004 All rights reserved.

Ecological economics is a transdisciplinary alternative to mainstream environmental economics. Attempts have been made to outline a methodology for ecological economics and it is probably fair to say that, at this point, ecological economics takes a “pluralistic” approach (see Norgaard, 1989). There are, however, some common methodological themes that run through the ecological economics literature. This paper argues that the works of Adolph Lowe and Robert Heilbroner can inform the development of some of those themes.

ENVIRONMENTAL AWARENESS IN THE WORKS OF LOWE AND HEILBRONER

Adolph Lowe and Robert Heilbroner both were aware of environmental-economic challenges from remarkably early on, and these issues gained an increasingly important place in their thought over the years. In his 1935 *Economics and Sociology*, Lowe wrote that:

In every epoch of human civilization, economic forces and institutions have deeply influenced the structure and evolution of society as a whole. But in modern history the economic process is, as we have seen, the dominant factor... The technique of the industrial age has broken through the traditional borders between the social and the natural world and has subjected more and more sections of organic and inorganic nature to human influence. This expansion, however, has reacted on the psychological and institutional constituents of modern society in a strange way. The more nature has become socialized, the more society has become naturalized. (Lowe, 1935, p. 153)

This idea that the economic system and economic process transforms not only the social, technical, and institutional, but also the natural environment, and that the latter therefore cannot be taken as “given” in economic analysis, remained an important theme in Lowe’s work for the remainder of his life and influenced Heilbroner’s own thinking. This position—already articulated in Lowe’s early work—was crucial for both authors’ thinking about the relation of the economy and the natural environment, and the impact of economic processes on the natural environment.

Heilbroner also expressed awareness of environmental challenges from an early date. In 1950, three years before the publication of his first book and thirteen years before he received his Ph.D., he wrote an article for *Harper’s Magazine* called “What Goes Up the Chimney,” inspired by the famous Donora incident. In the article, Heilbroner outlines the problems of pollution, its causes, and recommends some possible policies. Among his suggestions, he writes that “we must force large industry to add to its smoke-control equipment,” “we need better

smoke prevention,” and “we need smoke control enforcement.” This, twenty years before the first Earth Day.

While Lowe and Heilbroner both expressed awareness of environmental-economic challenges from very early on, in the late 1960s it moved to an even more prominent place in their thinking, with concern increasing over the next decades. In a widely reprinted 1970 article, “Ecological Armageddon,” Heilbroner writes that “[t]he ecological issue... may indeed constitute the most dangerous and difficult challenge that humanity has ever faced” (p. 270) and calls “the ecological crisis, unquestionably the gravest long-run threat of our times” (p. 285). He speaks of “[t]he necessity to bring our economic activities into a sustainable relationship with the resource capabilities and waste-absorption properties of the world,” and insists that “[t]he cult of disposability must be replaced by that of reusability,” writing that “[m]any of these problems will tax our ingenuity, technical and socio-political, but the main problem they pose is not whether, but *how soon*, they can be solved” (1970, pp. 281-282). Throughout this period, Heilbroner devoted considerable thought to the environmental challenge, including his frank testimony before the U. S. Congress on the National Energy Conservation Policy Act of 1974 (Heilbroner, 1974b; see also, e.g., Heilbroner, 1972; 1973).

Lowe’s increasing concern in the same period was inspired by his reading Geoffrey Vickers’ book, *Freedom in a Rocking Boat*. In a 1968 letter to Vickers, Lowe writes:

[T]he significance of the book for my own work lies in... your emphasis on ecology in the widest sense, and on the limits this sets to ‘progress’. As several times before, your work is a most important corrective for my own thinking, and after having digested your warnings I shall have to modify a good deal of what I have been provisionally committing to paper. (Vickers, 1991, p. 51)

From the late sixties and early seventies and onward, there is an explicit attempt by Lowe to incorporate environmental factors into his analysis. Thus, Part III of his 1976 book, *The Path of Economic Growth* is devoted to the analysis of natural resource inputs and the recycling of the residuals of both consumption and production. In his “Postscript” to the updated edition of his *On Economic Knowledge*, published one year later (1977), Lowe would write:

Recognition of the ecological triad—population explosion, gradual exhaustion of essential material resources, and progressive deterioration of the environment—has radically changed this picture [of economic growth]... [T]here is at this point no conceivable solution that would not imply a gradual reduction of the growth rate of the mature economies... [S]imultaneous industrial progress in all regions of the globe may well be incompatible with the available and even the potential supply of natural resources. Even more important, the ecosphere may not be able to

absorb the heat that the energy required for universal industrialization will emit. The answer can only be a gradual redistribution of the world's resources in favor of non-Western regions...resulting in a deceleration of Western economic expansion. (1977, pp. 340-41)

In the meantime, Heilbroner's own position expressed in the 1970 article was more fully elaborated in *An Inquiry into the Human Prospect* (1974a; hereafter HP). In HP, he includes population growth and environmental crisis as two of the three great challenges facing humanity in the 21st century. While Heilbroner feels that problems stemming from population growth and war might be avoided, he considers the environmental challenge as being in another category:

[T]here is an ultimate certitude about the problem of environmental deterioration that places it in another category from the dangers we previously examined...[U]ltimately there is an absolute limit to the ability of the earth to support or tolerate the process of industrial activity, and there is reason to believe we are now moving toward that limit very rapidly. (1974a, p. 47)

In his Afterword added to the 1980 edition, Heilbroner affirmed his view that “the crucial element today, as eight years ago, remains the environment—the ability of the planet to sustain the mushrooming of industrial output and to absorb the destruction that is the consequence of that vast human effort.” (1980, p. 67). And in his comments added to the 1991 edition, he remarks that “If anything, there is an uncomfortable feeling that environmental challenges are becoming worse,” although he adds with some hope that environmental awareness is also on the rise (1991, p. 75-76).

By 1988, Lowe's position had also solidified in this regard. In *Has Freedom a Future?* he writes:

[W]e find ourselves confronted with a host of difficulties that make it doubtful whether, in the long run, even the new technological revolution can achieve the required rate of economic growth. The impediments of which we are speaking are *ecological*: the triad of worldwide population explosion, gradual exhaustion of essential material resources, and the pollution of the environment. The significance of this complex is much wider than the context in which I introduce it here. Though slow in its advance, it may over the long run greatly modify mankind's style of life. All I want to demonstrate here, is that even under the most optimistic assumptions, it is an ecological factor that may ultimately block the growth of the west, as it is conventionally understood. (1988, pp. 48-49)

Heilbroner's position, too, has become increasingly clear in this recent period. In 1992, in his Foreword to the *Gaia Atlas of Green Economics*, Heilbroner embraces the “core...insistence” that “economics cannot be considered separately from...ecological concerns” (1992, p. 5).

Adolph Lowe and Robert Heilbroner have both clearly understood the challenges that humanity faces regarding the environment. Both expressed concerns long before economics as a discipline or society at large began to address these issues. And by the time the environmental challenges were more widely recognized, both were at the forefront in insisting that environmental issues be placed high on the agenda of economists and policymakers. Awareness of these and related concerns is what motivated the founding and development of ecological economics. Full consideration of biophysical and ecological realities leads to sustainability conditions or rules for a sustainable economy.

The insights of Lowe and Heilbroner are akin to those found and elaborated in the ecological economics' literature. Most ecological economists recognize that ecological and biophysical realities impose certain conditions on economic activity if sustainability is to be achieved (see, e.g., Lawn, 2001; Holmberg, et al., 1996; Prugh, et al., 2000). This recognition has led to investigations of the appropriate methodological foundations for ecological economics. But it is not only their work that explicitly addresses the environment or relates to environmental challenges that is relevant to the concerns of ecological economists. Heilbroner's *Worldly Philosophy* and Lowe's *Political Economics* offer insights that may prove useful in developing a methodology of ecological economics.

ADOLPH LOWE AND HEILBRONER'S WORLDLY PHILOSOPHY

As readers of Heilbroner's *The Worldly Philosophers* (1953) may recall, Heilbroner became interested in the lives, times, and ideas of the great political economists after registering for a class on Smith, Ricardo, and Marx at the New School for Social Research in the mid-forties with Adolph Lowe. It was not simply that Lowe inspired an interest in political economy; Heilbroner adopted Lowe's basic *vision* as outlined in the latter's *Economics and Sociology*, his article "The Classical Theory of Economic Growth" (1954), and related writings. This included not only the interpretation of the great Classical Political Economists such as Smith, Ricardo, and Marx (both considered Marx in many ways the zenith of Classical Political Economy), but the interpretation of later writers such as Keynes, Schumpeter, and Veblen as fundamentally in this same tradition, and the sharp contrasting of this tradition with that of neoclassical economics, with its ahistorical, overly formalist, methodological individualist, and positivist character.

For Lowe, the static equilibrium models of neoclassical economics were inadequate to analyze the “dynamic chain of reciprocal causation” at work in industrial capitalism (Lowe, 1935, pp. 138-39). Instead, what was required was a theoretical approach that could endogenize the structural factors taken as given in standard presentations. Economic analysis must be accompanied “by a theory of the evolution of its...data” since “[t]he essential variations of those data [are] effected” by economic processes themselves (Lowe, 1935, pp. 93-96). Lowe was even dissatisfied with twentieth century work on economic dynamics precisely due to the fact that the “time honored distinction between dependent and independent variables — that is, between an economic process and the underlying meta-economic forces which drive it on and change it — is generally maintained” (Lowe, 1954, p. 128). Even “dynamic process analysis” was “but a dim reflection” of what is found in the classics and Marx (Lowe, 1954, p. 128). In fact, Lowe argued that it is the “issue of endogeneity versus exogeneity, rather than conflicting theories of value” that separates “genuine classical theory” from “post-Millian economic reasoning, including all versions of neoclassical analysis” (Lowe, 1954, p. 129). The issue regards:

the entire possible range of deductive reasoning. Let us be quite clear about the disputed region. It concerns the whole natural, social and technical environment of the economic system... and...the changes in these elements through time. [For the Classical Economists and Marx] the explanation of the order and changes of these data itself formed part of the theoretical work of economists. (Lowe, 1954, pp. 129-30)

For Lowe, then, the classical economists applied their method over a much wider range than the neoclassical authors, to include the social-historical and environmental context of economic processes. Thus, for Lowe an evolutionary approach would aim to once again “extend the range [of analysis]... to the sphere of the natural and social data of the market process, and thus to facilitate an estimate of the direction and limits of possible dynamic changes of the system as a whole” (1935, p. 67). In this view, the classical approach considers areas thought to be outside the scope of economics in the neoclassical view—areas falling broadly under the headings of the social-historical and environmental contexts of economic processes—as legitimate targets of analysis (for more on this, see Forstater, 2003).

This dynamic, sweeping vision of capitalism as a deterministic social system where impersonal forces move history and endogenous processes result in ongoing systemic transformation was clearly adopted by Heilbroner. In *The Worldly Philosophers*, he

outlined their dramatic scenarios depicting the almost inexorable movement of the capitalist system, with its “laws of motion”—systematic tendencies leading to some predetermined conclusion. Underlying the system’s movement were a variety of factors, both economic and non-economic. In other words, the trajectory of the system was inseparable from the wider sociopolitical and environmental context within which the economy is situated.

In his analysis, Heilbroner adopted his own versions of Schumpeter’s (1954) notions of “vision” and “analysis.” Whereas for Schumpeter (also a former professor of Heilbroner) analysis had a kind of “cleansing” effect, which prevented the necessarily ideological nature of the “pre-analytical cognitive act” from tainting the scientific endeavor, for Heilbroner economic theory is inescapably value-laden. Biases are always present, at times lurking just beneath the surface but often emerging in the form of assumptions that determine the content of their analytical categories and the direction of their prognostications, thus the importance of his notions of scenario, vision, analysis, and ideology. A scenario is a “complex narrative...combining many prognoses” (Heilbroner, 1990, p. 1111). Visions are not scenarios; rather, they are “the source, but not the determinants of social prognoses” (Heilbroner, 1990, p. 1111). Neither are visions the result of scenarios; they are “pre-analytical.” The directions of the prognoses are the result of logical analysis, which, however, can never be completely independent of either vision or ideology. Scenarios thus “combine powerful analytical frameworks with highly personalized visions concerning the motives and behaviors of the actors within those frameworks” (Heilbroner, 1993, p. 122). The distinction between vision and ideology depends on whether one’s pre-conceptions and sociopolitical orientation are made explicit, or whether they are hidden and even denied: “That which we call ideology is therefore perhaps best understood as unrecognized vision, and that which I call vision as consciously embraced ideology.” (Heilbroner, 1994, p. 329)

In recent years, Heilbroner has questioned whether, under present contemporary circumstances, “Worldly Philosophy” is still possible. He believes that scenarios and visions do not lend themselves to formal analytical procedures. More importantly, he believes that the economic behaviors that set the system on its path have become less dependable, while political intervention has become more strategic. Lowe, too, by the mid-fifties, began to develop the thesis that historical changes in the structure of capitalist society had altered the object of inquiry in such a way as to necessitate the abandoning of the traditional approach, requiring that analysis henceforth be conducted within an alternative, “instrumental” methodological

framework. Rather than taking only the initial conditions as given and addressing theory to predicting outcomes, Lowe proposed also taking as given a pre-determined end-state: a vision of the desired outcomes. The task then becomes the derivation—the discovery—of the technical and social path(s) by which these outcomes might be achieved (structural analysis), the behavioral and motivational patterns capable of setting the system onto a suitable path (force analysis), the environmental context(s) capable of encouraging or inducing these patterns, and policies shaping/creating the environmental context(s).

Heilbroner similarly came to the conclusion that an instrumental approach, in Lowe's sense, had become more appropriate, with "blueprints depicting possible routes from present realities to desired destinations" replacing "scenarios depicting a future immanent in the present" (Heilbroner, 1992, p. 381; see also, Heilbroner and Milberg, 1995, pp. 118ff; Forstater, 1999). A key issue for Heilbroner is the increasing "openness" of the system. The determinism of the Classical system was rooted in "laws" which were seen to govern relations between such factors as population (labor supply), subsistence (wages), natural resources, employment, and technical change. The "iron law of wages," the "law of population," "the (Classical) law of diminishing returns," were seen as natural, so unalterable. As Lowe observed, in the Classical era, "impersonal forces or 'laws' which might be observed or interpreted, but which *could not be altered*" appeared to govern such relations, but scientific and technological advance later transformed most of these law-like relations into variable ones, capable of human influence: "That which once 'happened,' can now be made to happen, or prevented from happening" (Lowe, 1971, p. 568). Furthermore, having created the technological potential to both induce and prevent disaster, humankind has "no alternative to accepting the challenge of the new era":

In the face of this tremendous enlargement of human capabilities, there is no possibility of turning away. Even doing nothing, or outlawing the advance of our further capabilities, would be as much an act of intervention as exploiting our newfound capabilities to our utmost. (Lowe, 1971, p. 568)

More than anything else, it may be this existential predicament that concerns Heilbroner. As Lowe put it: "From now on, the future will have to be more and more the result of our deliberate choices, at every level of human activity" (Lowe, 1988, p. 2).

THE METHODOLOGY OF ECOLOGICAL ECONOMICS

The methodology of ecological economics utilizes the notions of vision, analysis (including structural analysis), scenarios, and implementation (synthesis):

...making sustainability operational requires the integration of three elements: (1) a practical, shared *vision* of both the way the world works and of the sustainable society we wish to achieve; (2) methods of *analysis* and modeling to the new questions and problems this vision embodies; and (3) new institutions and instruments that can effectively use the analyses to adequately *implement* the vision. (Costanza, et al., 1996, p. 1)

This is reflected in the section headings of the book from which the above quote is taken, *Getting Down to Earth*, a key text in ecological economics. Chapters in the book are organized under three themes: “Vision,” “Analysis,” and “Implementation” (1996, Table of Contents).

Ecological economists are virtually unanimous in their view that work must begin with *vision*:

If most policy discussion focuses on implementation, virtually all the rest focuses on modeling and information. This leaves just about no room for the remaining step of policy formation, which should be first—the establishment of clear, feasible, socially shared goals. (Meadows, 1996, p. 118)

It is no surprise, then that one of the most common methodological principles found in ecological economics regards the importance and necessity of vision:

A broad, overlapping consensus is forming around the goal of sustainability, including its ecological, social, and economic aspects... But movement toward this goal is being impeded not so much by lack of knowledge, or even lack of “political will,” but by a lack of a *coherent, relatively detailed, shared vision of what a sustainable society would actually look like*. Developing this shared vision is an essential prerequisite to generating any movement toward it. The default vision of continued, unlimited growth in material consumption is inherently unsustainable, but we cannot break away from this vision until a credible and desirable alternative is available. (Costanza, et al., 1997, pp. 177-178)

Note the similarities between Costanza, et al.’s notion of the “default vision” and Lowe’s argument, quoted above, that “even doing nothing... would be as much an act of intervention.”

Here we see that the notion of vision, which many ecological economists—like Heilbroner—explicitly draw from Schumpeter, is used both as a means of deconstructing the inadequacies of the mainstream approach and building a positive alternative. Lawn writes that:

in many ways, the development of an ecological economic paradigm has been a concerted attempt to overhaul the standard neoclassical approach by bringing the many false “pre-analytical visions” underpinning its assumptions into line with biophysical and existential realities. (Lawn, 2001, p. 3)

But the ecological economist must be careful that recognizing the biophysical realities does not result in being overwhelmed by them: “Responsible vision must acknowledge, but not get crushed by, the physical constraints of the real world” (Costanza, et al., 1997, pp. 179).

As with Heilbroner and Schumpeter, ecological economists view vision as “pre-analytical.” Visions are not the result of analysis, and crafting a vision requires imagination:

Building a responsible, desirable vision of a sustainable world is partly a rational process, subject to analysis of what is possible over what time frame. But it is also a non-rational or perhaps supra-rational task of imagination, one that comes not only from logic but from values. (Meadows, 1996, p. 117)

As Prugh, et al., put it: “The rational process of figuring out how to achieve a sustainable world must begin with a nonrational act of imagination” (Prugh, et al., 2000, p. 41). As we will see, nonrational mind will play an important role also in analysis and scenario-building as well.

But what is being developed here is not some kind of vision/science dichotomy: “This need for appropriate vision applies to every aspect of human endeavor. Far from being immune to this need for vision, science itself is particularly dependent on it” (Costanza, et al., 1996, p. 3). In fact, another important characteristic of the ecological economics approach is a rejection of the positive/normative dichotomy. “Vision” includes both positive and normative elements; in ecological economics, the relationship of positive and normative is “best viewed as a complex interaction across a continuum, rather than a simple dichotomy” (Costanza, et al., 1996, p. 2).

In such an approach, “[v]ision has to be flexible and evolving” (Costanza, et al., 1997, pp. 179). This allows vision—like analysis, as we shall see—to become both a skill that can be improved: “The skill of visioning is one that can be developed, like any human skill, through practice” (Meadows, 1996, p. 117); and itself a method of problem-solving:

Vision has an astonishing power to open the mind to possibilities... Vision widens my choices, shows me creative new directions. It helps me see good-news stories, pockets of reality that could be seeds of a wider vision. (Meadows, 1996, p. 123)

Visions and envisioning are at the heart of the methodology of ecological economics (see also Costanza, 2001). A vision of a sustainable society is a necessary pre-requisite to devising policies for its attainment. Moreover, visions and the envisioning process can assist in the discovery of such policies. Vision is where everything starts—it is pre-analytical. As such, what follows the vision is *analysis*. Analysis attempts to link the imagined future back to the present reality:

visions can heighten the contrast between what is and what might be. They also can suggest starting points for effecting a transition from the one to the other. (Prugh, et al., 2000, p. 44)

Ecological economics uses structural analysis to build scenarios. Scenario here is used somewhat differently than in Heilbroner's discussion of the worldly philosophers' scenarios. In the latter case, a scenario was a dramatic set of prognoses concerning where the system was heading; scenario here is a possible route leading to the vision of the future:

In structural economics each scenario about the future could (if one wished) be viewed as a hypothesis or an experiment. But the feasibility at issue is mainly that of the scenario itself, or perhaps of a family of related scenarios, rather than the validity of the theory or model. (Duchin, 1998, p. 6)

Like visions, scenarios combine elements traditionally viewed as either positive or normative:

Scenario storylines can embody a mixture of prospective elements (these being descriptive of a possible future) and normative elements (these being 'intended' or 'desired' aspects); but the way these elements combine together can vary a lot. (Ryan, et al., 1998, p. 239)

Thus, analysis in ecological economics does not employ the traditional hypothetico-deductive method (Duchin, 1998, p. 6). Crafting scenarios, like visions, also draws on imagination:

[T]he fundamental challenge facing civic society today is to figure out what our options are for dealing with social and environmental problems. This requires an act of imagination—the ability to describe novel, untried, but plausible solutions that could represent dramatic departures from present practices... Interestingly, the scientific tradition explicitly acknowledges the importance of curiosity about how things work, but not of imagination—the ability to conceive of how things might work differently. Subsequently, the alternative options, based on imaginative scenarios, require systematic analysis to determine their feasibility and other characteristics... The scenarios are a translation of the acts of imagination about what could be done into the language of the model. (Duchin, 1998, p. 5)

Thus imagination works in tandem with analysis, including multiple forms of problem-solving approaches:

Not only imagination but also inductive reasoning and intuition play a large and explicitly recognized role in the development of theory in structural economics. (Duchin, 1998, p. 6)

The nature of environmental challenges means that we cannot afford to allow economics to determine the "ends" as in the traditional approach, which claims to find the "optimal level of pollution" through Pigouvian taxes or fees. Instead, the ends are derived through careful consideration of available scientific information and the "precautionary principle" of erring on

the side of caution. Analysis then “works backwards” from the vision of the desired ends to find suitable sustainable paths for its attainment:

Pervasive externalities, such as the possibility of global climate change, have countless facets and are created by such a vast, complex, interdependent and difficult-to-assess web of economic actions that the calculation of the myriad taxes necessary to get the price right is beyond human capability and would be meaningless even if possible. In these cases, *it would be more sensible to work backwards* (my emphasis) from a determination of the maximum possible *scale* (or better yet, the optimum desirable scale) of the global economy, which is more readily definable, and then let [economics work] within those limits. (Prugh, et al., 1995, pp. 132-133)

Of course, “ends” are not static, and the means-ends dichotomy is also rejected. Rather, an adaptive and flexible approach is taken that continuously re-evaluates each situation in the light of new developments and new information:

The path toward a vision reveals new information, models, and possibilities as one moves along. (Meadows, 1996, p. 123)

Movement toward sustainability will have to be incremental and adaptive (open to feedback). (Prugh, et al., 2000, p. 61)

The principles of flexibility and adaptability emphasized by ecological economists mean that the researcher must remain open to making adjustments:

the implementation path is never clear at first. It only reveals itself, step by step... holding to the vision and being flexible about the path is the only way to find the path. (Meadows, 1996, p. 122)

This is especially important given ecological economists recognize radical or fundamental uncertainty:

[Adaptive management is] an approach to natural resource policy that embodies a simple imperative: policies are experiments; learn from them. In order to live, we use the resources of the world, but we do not understand nature well enough to know how to live harmoniously within environmental limits. Adaptive management takes that uncertainty seriously, treating human interventions in natural systems as experimental probes. (Kai Lee, 1993, p. 9, quoted in Prugh, et al., 2000, p. 32)

While ecological economics has taken a pluralistic approach to methodological issues, there are common themes that can be found in the ecological economics literature. The importance of vision, analysis (including structural analysis), scenarios, and implementation are discussed over and over again by ecological economists. The meaning of these terms in ecological economics is related but not identical to their use in Heilbroner’s worldly philosophy. But the ecological economists’ use of the terms is very close to their use in Lowe’s Political

Economics or instrumental analysis, also supported by Heilbroner as the appropriate method for the contemporary era.

LOWE'S POLITICAL ECONOMICS AND INSTRUMENTAL ANALYSIS

Heilbroner and Lowe both came to the conclusion that, in a sense, worldly philosophy is no longer possible. Nevertheless, rather than the notions of “vision,” “analysis,” and “scenario” being thrown away, they need only to be modified in the context of Lowe’s instrumental analysis. *Vision* in this context refers to Heilbroner’s “desired destinations”—goals such as a sustainable society. *Scenarios* here are possible routes connecting the vision of the desired future back to the present—Heilbroner’s “blueprints.” *Analysis* in this context is the method of discovery—the means by which scenarios are discerned. The distinction between vision and ideology still holds—a vision is not ideology (in the negative sense) as long as it is consciously stated and critically examined. Thus Heilbroner’s worldly philosophy remains relevant as well.

In Lowe’s instrumental method, rather than taking only the initial conditions as given and addressing theory to predicting outcomes, he proposed also taking as given a pre-determined end-state: a vision of the desired outcomes. The task then becomes the derivation—the discovery—of the technical and social path(s) by which these outcomes might be achieved (structural analysis; note Lowe uses this term in the same sense as Duchin, not surprising since the latter was a protégé of Lowe’s colleague at Kiel University in the 1920s, Leontief), the behavioral and motivational patterns capable of setting the system onto a suitable path (force [i.e., motivational and behavioral] analysis), the environmental context(s) capable of encouraging or inducing these patterns, and policies shaping/creating the environmental context(s). The instrumental method is thus a *regressive* procedure, beginning from where we want to go (pre-analytical vision) and working backwards (analysis) to our present state, or a state within our present reach (Lowe, 1977[1965]: 143-44). The derivation of a suitable path is a scenario. It is derived by working backwards. Now the execution of the plan may commence, working forward from our present state along the path we have outlined via the analysis.

Lowe briefly mentions in several places the affinity of his instrumentalism with certain ideas of others. In particular, he cites the pragmaticist philosopher Charles Sanders Peirce’s concept of “retroduction” (and especially Norwood Hanson’s elaboration of that concept), the mathematician Georges Polya’s work on “heuristics”, and physical chemist and philosopher of

science Michael Polanyi's explorations of "tacit knowledge" as all bearing strong family relationships with aspects of his instrumentalism (see Forstater, 1999).

Polya devoted much work to heuristics, whose aim he states is to "study the methods and rules of discovery and invention" (1957 [1945], p. 112). Central to heuristics is the regressive procedure Polya refers to as "working backwards." Polya notes that the Greek geometers, who called the procedure "analysis" (meaning "solution backwards" in Greek), attributed its discovery to Plato (Polya, 1984[1958], pp. 575-76). Consider Polya's translation of a passage from the seventh book of Pappus' *Collectiones* concerning "analyomenos," which Polya translates as "Treasury of Analysis," "Art of Solving Problems," or "Heuristic" (Polya, 1957 [1945], p. 141):

In analysis, we start from what is required, we take it for granted, and we draw consequences from it, and consequences from the consequences, till we reach a point we can use as a starting point in synthesis. For in analysis, we assume what is required to be done as already done (what is sought is already found, what we have to prove as true). We inquire from what antecedent the desired result could be derived; then we inquire again what could be the antecedent of that antecedent, and so on, until passing from antecedent to antecedent, we come eventually upon something already known or admittedly true. This procedure we call analysis, or solution backwards, or regressive reasoning. (*ibid.*, p. 142)

This procedure is contrasted with synthesis:

[I]n synthesis, reversing the process, we start from the point which we reached last of all in the analysis, from the thing already known or admittedly true. We derive from it what preceded it in the analysis, and go on making derivations until, retracing our steps, we finally arrive at what is required. This procedure we call synthesis, or constructive solution, or progressive reasoning. (*ibid.*)

Synthesis, Polya writes, is "translation of the ideas into action," or implementation (*ibid.*, p. 145):

The same objects fill the analysis and synthesis; ...the analysis consists in thoughts, the synthesis in acts. There is another difference; the order is reversed... [T]he first desire from which the analysis starts...is the last act with which the synthesis ends... Analysis comes naturally first, synthesis afterwards; analysis is invention, synthesis execution; *analysis is devising a plan, synthesis carrying through the plan.* (*ibid.*, pp. 145-46).

"Observe," urges Polya, "planning and execution proceed in opposite directions" (Polya, 1981 [1962], p. 23). "[T]he aim is the first thing we thought of and the last thing we laid hands on" (*ibid.*).

Ecological economists such as Costanza have emphasized the importance of both analysis and synthesis:

The arts focus on teaching people to *synthesize*, the sciences focus on teaching people to *analyze*. All human activities require a balance between synthesis and analysis... our educational system could benefit...by a much more explicit attempt to teach both synthesis and analysis skills...across the entire academic spectrum. (1997, p. xiii)

Here the notions of analysis and synthesis are left underdeveloped. It may be that, given ecological economists' recognition of the necessity of working backwards from a pre-analytical vision of the desired future to the present state, adoption of the Lowe/Polya notions of analysis and synthesis may aid in the development of the methodology of ecological economics.

In addition to Polya's heuristics, Lowe also likens the instrumental method to Peirce's abduction or retroduction. These terms refer to what Peirce described as a third type of inference in addition to deduction and induction. For Peirce, retroduction is the only kind of inference that is capable of creating new knowledge. Peirce follower and elaborator Norwood Hanson finds the following distinction useful:

- 1) reasons for accepting some hypothesis H
- 2) reasons for entertaining some hypothesis H

Retroduction concerns the second; it is about hypothesis formulation and selection, rather than rejecting or accepting some already formulated hypothesis. Retroduction is complementary to deduction and induction, but retroduction is the "first step in scientific reasoning" (Fann, 1970, p. 35). Once an hypothesis is adopted, the next step is "to trace out its necessary and probable consequences. This step is deduction" (Peirce, CWVII, p. 203). The next step is to compare the actual results with what was expected, that is induction. Likewise, Lowe also sees a role for deductive and inductive reasoning as complementing retroduction. We have seen that ecological economists refer to other types of reasoning (Duchin's reference to "not only imagination but also inductive reasoning and intuition" above), but they have not (to my knowledge) explored the role of retroduction. Since Peirce refers to retroduction as reasoning from consequent to antecedent, or inferring a cause from its effect—i.e. working backwards—it may assist ecological economics in developing its methodology to explicitly explore the notion.

Like ecological economists, Lowe's framework rejects the positive/normative dichotomy. Lowe refers to the approach that begins analysis without consideration of a vision of the future as "a radical positivism interested only in the explanation and prediction of

movements ‘wherever they might lead’” (Lowe, 1969, p. 7). For Lowe, the separation of the positive and normative “can no longer be justified;...recent developments demand the conscious integration of the analytical and normative aspects” (1967, p. 180).

Peirce and Hanson disagree with the common view that there is no “logic of scientific discovery.” For Peirce, retrodution is not bogged down by rules, but it does have a logical form:

The surprising fact C is observed.

If A were true, C would be a matter of course.

Hence there is reason to expect that C may be true. (CWV, p. 189)

Here, Peirce is retroduting from the present to the past, while Lowe’s instrumental inference, like ecological economics, is moving from the vision of the desired future to the present, but both are employing the regressive procedure.

We have seen above that Duchin contrasts the ecological economists’ method of structural analysis with the hypothetico-deductive method. Lowe and Hanson similarly reject hypothetico-deductive reasoning as irrelevant for instrumental or abductive inference (Lowe sees a role for deduction, but this is what he calls instrumental-deduction rather than hypothetic-deduction, since the conditions are not given, but must be stated by the vision).

Hanson, following Peirce, has investigated the difference between retroductive and deductive reasoning to highlight both that there is a logic to retrodution and that its logic is distinctive. One scientist argues from premises A, B, C and hypothesis H to conclusion D. Another encounters an anomaly D, and “cojoins this statement with A, B, and C so as to ‘corner’ an hypothesis H which, when bracketed with A, B, and C will possibly ‘explain’ D. Both scientists are arguing, both have been using their brains. Differently!” (Hanson, 1965, p. 64). Whether one works the problem from the bottom up or the top down, the question is whether there is a route connecting A, B, C with D. The logical form of the argument once we have worked backwards to the beginning looks the same: some logical route connects A, B, C, H with D. We can state this regardless of whether we have arrived at this state via progressive reasoning from A, B, C, H to D or regressive reasoning from D back to A, B, C, H. Likewise, Hanson argues, if no route connects A, B, C, and H to D then neither retrodution from D or hypothetic-deduction from A, B, C, H will be forthcoming (1965, p. 58). But, he insists, the “de

facto conceptual development within the problem-solving context...are different” in the two cases, “and not only psychologically so!” (1965, p. 61).

Insight into a key difference is provided by Hanson:

From...A, B, C, H, any two result[s]...(e.g., D₁ and D₂) *must* themselves be consistent.

Whereas, given any two sets of premises—A, B, C, H as against A', B', C', H'—either of which may resolve...D, it is not the case that these be mutually consistent. (1965, p. 61)

The point is to get to D. Working backward from D, we may find a number of routes, say A, B, C + H₁ or H₂ or H₃, *where there is no need for the Hs to be mutually consistent—they are alternative suitable paths* (Hanson, 1965, pp. 60-61). Working forward from A, B, C + H, all the members of the attainable set D_{1,2,3...n} must be mutually consistent; there may be better paths, but we will not find them working forward: we may not find a suitable path, or we may not find the best suitable path. Moreover, Lowe stresses that *it is through the instrumental procedure that we discover the Hs themselves*:

If it is true that...rules are indispensable data for instrumental analysis, why bother with a regressive derivation of the suitable path instead of deducing them in the usual fashion from the knowledge of the rules and the initial conditions? The answer is simple. Once we *know* which members of the total set of...rules are goal-adequate, we can indeed deduce the path in the conventional manner. *The first step of instrumental analysis is to provide us with precisely this knowledge.* (Lowe, 1969, p. 183).

Like the ecological economists, Lowe's notion of instrumental inference recognizes that problem solving requires going beyond the rational. Instrumental inference is characterized by Lowe as a “search procedure” and “a mental technique of problem-solving” in which solutions are “discovered” or “hit upon...through what [Michael] Polanyi calls a logical ‘leap’” (Lowe, 1977 [1965], p. 145): “But they are not leaps in the dark...[O]ur search is guided by past experience, analogies, and other clues. Yet it remains true that our ultimate insight springs from a non-rational act of ‘imagination’” (Lowe, 1992, p. 327).

Lowe and the ecological economists share an emphasis on the role of non-rational imagination. While ecological economists mention it, and many certainly exercise imagination, the literature does not really explore it much further. Lowe, drawing on Polya, Peirce, Polanyi and others, explores the procedure further, and in ways that may assist ecological economists. Polya has identified the “first task” as that of “collect[ing] and classify[ing] such problem solving procedures” and to “develop a repertory of problem solving techniques” (1984[1971], p. 590). Even this will not solve the problem comprehensively, because there is still the task of

choosing among the available techniques, a decision that will require that the investigator “use personal judgment, as Polanyi would say.” This is similar to Lowe’s discussion of choosing from among alternative hypotheses:

There are no binding rules, according to which the researcher could decide in favor of one among many possible hypotheses. Which one he chooses in the end, adopting...Einstein’s ‘free creation of the mind’, is neither a strictly determinable nor an arbitrary decision. (Lowe, 1992, p. 327).

For Polanyi, appreciation of a problem is itself part of the act of discovery (1958, p. 121). Seeing a problem “is a definite addition to our knowledge,” and “to recognize a problem that can be solved and is worth solving is a discovery in its own right” (1958, p. 120). In the process, a “heuristic stress” builds, which is akin to an emotional strain on the part of the investigator. Discovery leads to a release, e.g., running through the streets crying “Eureka!” (1958, p. 122).

One heuristic tactic noted by Polanyi is to continuously reorganize the problem “with a view to eliciting some new suggestive aspects of it” (1958, p. 128). This is reminiscent of C. Wright Mills’ suggestion that “the re-arranging of the [researcher’s] file...is one way to invite the [sociological] imagination (1959, p. 212):

Imagination is often successfully invited by putting together hitherto isolated items, by finding unsuspecting connections...As you re-arrange a filing system, you often find that you are, as it were, loosening your imagination. Apparently this occurs by means of your attempt to combine various ideas and notes on different topics. It is sort of a logic of combination, and ‘chance’ sometimes plays a curiously large part in it. In a relaxed way, you try to engage your intellectual resources...Of course, you will have in mind several problems on which you are actively working, but you also try to be passively receptive to unforeseen and unplanned linkages (Mills, 1959, p. 201, 212)

Both Polanyi and Mills relate this “reorganizing” tactic with another, what Polanyi refers to as “ransack[ing] our memory for any similar problem” (1958, p. 128) and Mills calls “get[ting] a *comparative* grip on the materials” (1959, p. 215). Polya writes:

Any conjecture, of course, must have been suggested...by somehow related ideas (special cases, analogies, etc.), although, perhaps, at the moment of conceiving the conjecture those ideas were not clearly and explicitly present. (Polya, 1984[1948], p. 474)

Thus, writes Lowe, in seeking to discover the suitable path or paths to the realization of the vision of the desired outcomes, “our search is guided by past experience, analogies, and other clues” (Lowe, 1992, p. 327).

In the course of the heuristic search, we must look for “favorable signs,” which of course must not be mistaken for “proof” but which encourage “further investigation” (Polya, 1984[1948], p. 490). Lowe cautions that “the findings of heuristic analysis can be accepted only provisionally” (1992, p. 327). Polya invokes the notions of the “bright idea” and “feeling we are ‘on the right track’” to get at the seemingly intuitive aspects of the discovery procedure (*ibid.*). For Polanyi, “success depends ultimately on the capacity for sensing the presence of yet unrevealed logical relations between conditions of the problem, the theorems unknown..., and the unknown solution...” (1958, p. 128). Polanyi invokes the “common experience(s) of groping for a forgotten name” and searching for a name or word that is said to be “on the tip of the tongue” to illustrate the “sense of growing proximity to the solution” that guides discovery (1958, pp. 128-29). As Lowe puts it, the “researcher ‘senses’ a structural relationship between the hypothesis he chooses and the problem he wants to solve” (1992, p. 327).

Equally important is Polanyi’s suggestion that self-awareness of the capacity to sense the “accessibility of a hidden inference,” as well as of the ability to “invent transformations of the premises which would increase accessibility” is a “foreknowledge” which itself “biases our guesses in the right direction” (1958, p. 129). The discovery-enhancing effects of our ability to discover is also related by Polanyi to the fact that “a set purpose may automatically result in action later on” as when we go to bed resolved to wake up at a certain hour and then do (*ibid.*). These factors also help explain the “self-accelerating manner of the final stages of solution,” i.e., the closer we get the faster we progress (*ibid.*). These aspects of discovery are not treated lightly by Polanyi, who takes the position that “the whole process of discovery and confirmation ultimately relies on our own crediting of our own vision” (1958, p. 130).

Echoing the remarks of the ecological economists above, Peirce also believed abductive reasoning to be “a skill that could be improved by practice or discipline” (Ochs, 1993, p. 61). And all the authors also see important roles for both common-sense and imagination in discovery.

Lowe’s Political Economics, with its instrumental analysis, has some important points of contact with themes raised in discussions of the methodology of ecological economics. But while ecological economics has raised certain issues, it has not elaborated them. It has been the purpose of this section to not only point out some of the connections, but to give a peek at the elaborations that ecological economists may find useful.

CONCLUSION

Adolph Lowe and Robert Heilbroner were both aware of the environmental challenges facing humanity from quite early on in their work and quite ahead of their time. In addition, both Lowe's *Economics and Sociology* (and related writings) and Heilbroner's *Worldly Philosophy* (itself influenced by this work of Lowe) recognized the endogeneity of the natural environment, the impact of human activity on the environment, and the implications of this for questions of method. Lowe and Heilbroner also became increasingly concerned with issues related to the environment over time, such that these issues became of prime importance in their frameworks. This work deals directly with the ecological and environmental issues; both authors also dealt with other issues that relate to the environmental challenge, such as technological change. But it is not only their work that explicitly addresses the environment or relates to environmental challenges that is relevant to the concerns of ecological economists. Heilbroner's *Worldly Philosophy* and Lowe's *Political Economics* offer insights that may prove useful in developing a methodology of ecological economics. The connections are almost uncanny. Ecological economists have taken a pluralistic approach to methodology, but the common themes in this work regarding the importance and nature of vision, of analysis (including structural analysis), scenarios, implementation, of the necessity of working backwards, of the role for imagination, rejecting the hypothetico-deductive method and the positive/normative dichotomy, and so on, all are issues that have been elaborated in Lowe's work, and in ways that are relevant to ecological economics. There are additional issues that we have not had time to elaborate—Heilbroner's *Visions of the Future*, e.g., would merit another whole section, at least. But the goal of the paper is actually quite modest: to make ecological economists aware of the works of the two authors, and get them interested enough to explore the possible contribution of these ideas to their methodological approach.

BIBLIOGRAPHY

- Costanza, Robert. 1997. "Introduction: Building Transdisciplinary Bridges at the Frontiers of Ecology and Economics." In *Frontiers in Ecological Economics*. Cheltenham, U.K.: Edward Elgar.
- Costanza, Robert. 2001. "Visions, Values, Valuation, and the Need for an Ecological Economics." *Bioscience*. 51 (6): 459-468.
- Costanza, Robert, Olman Segura, and Juan Martinez-Alier. 1996. "Integrated Envisioning, Analysis, and Implementation of a Sustainable and Desirable Society." In R. Costanza, O. Segura, and J. Martinez-Alier (eds.), *Getting Down to Earth*. Washington, D.C.: Island Press.
- Costanza, Robert, John H. Cumberland, Herman E. Daly, Robert Goodland, and Richard B. Norgaard. 1997. *An Introduction to Ecological Economics*. Boca Roton, FL: St. Lucie Press.
- Duchin, Faye. 1998. *Structural Economics*. Washington, D.C.: Island Press.
- Fann, K. T. 1970. *Peirce's Theory of Abduction*. The Hague: Martinus Nijhoff.
- Forstater, Mathew. 1999. "Working Backwards: Instrumental Analysis as a Policy Discovery Procedure." *Review of Political Economy*. 11 (1): 5-18.
- Forstater, Mathew. 2003. "Cumulative Causation à la Lowe: Radical Endogeneity, Methodology, and Human Intervention." In G. Argyrous, M. Forstater, and G. Mongiovi, (eds.), *Growth, Distribution, and Effective Demand: Alternatives to Economic Orthodoxy: Essays in Honor of Edward J. Nell*. Armonk, N. Y.: M. E. Sharpe.
- Hanson, Norwood. 1965. *Patterns of Discovery*. Cambridge: Cambridge University Press.
- Heilbroner, Robert. 1950. "What Goes Up the Chimney." *Harper's*.
- Heilbroner, Robert L. 1953. *The Worldly Philosophers*. New York: Simon and Schuster.
- Heilbroner, Robert. 1970. "Ecological Armageddon." In *Between Capitalism and Socialism*. New York: Random House.
- Heilbroner, Robert. 1972. "Growth and Survival." *Foreign Affairs*. 51(1): 139-153.
- Heilbroner, Robert. 1973. "Economic Problems of a 'Postindustrial' Society." *Dissent*. 20 (2): 163-176.
- Heilbroner, Robert. 1974a. *An Inquiry into the Human Prospect*. New York: W. W. Norton and Co. (additional editions, 1980; 1991).

- Heilbroner, Robert. 1974b. Statement of Dr. Robert Heilbroner, Economist, New School for Social Research, New York City., Hearings Before the Subcommittee on the Environment on H.R. 11343, National Energy Conservation Policy Act of 1974., Ninety-Third Congress, Second Session, Hearings held June 4, 6, and 10; July 19 and 26, 1974., Serial No. 93-55., U. S. Government Printing Office, Washington, D.C.
- Heilbroner, Robert. 1990. "Analysis and Vision in the History of Modern Economic Thought." *Journal of Economic Literature*. 28 (3): 1097-1114.
- Heilbroner, Robert. 1992. "Is Worldly Philosophy Still Possible? Adolph Lowe as Analyst and Visionary." *Review of Social Economy*. 50 (2): 374-382.
- Heilbroner, Robert. 1992. Foreword. In *The Gaia Atlas of Green Economics*. New York: Anchor Books.
- Heilbroner, Robert. 1993. *21st Century Capitalism*. New York: W. W. Norton & Co.
- Heilbroner, Robert. 1994. "Vision in Economic Thought." *Journal of Economic Issues*. 28 (2): 325-329.
- Heilbroner, Robert. 1996. *Teachings From the Worldly Philosophy*. New York: W. W. Norton & Co.
- Heilbroner, Robert, and William Milberg. 1995. *The Crisis of Vision in Modern Economic Thought*. Cambridge, UK: Cambridge University Press.
- Holmberg, John, et al. 1996. "Socio-Ecological Principles for a Sustainable Society." In R. Costanza, O. Segura, and J. Martinez-Alier (eds.), *Getting Down to Earth*. Washington, D.C.: Island Press.
- Lawn, Philip A. 2001. *Toward Sustainable Development*. Boca Roton, FL: Lewis Publishers.
- Lowe, Adolph. 1935. *Economics and Sociology*. London: George Allen & Unwin.
- Lowe, Adolph. 1954. "The Classical Theory of Economic Growth." *Social Research*. 21: 127-158.
- Lowe, Adolph. 1976. *The Path of Economic Growth*. Cambridge: Cambridge University Press.
- Lowe, Adolph. 1977 [1965]. *On Economic Knowledge*. Enlarged Edition, Armonk, N.Y.: M. E. Sharpe.
- Lowe, Adolph. 1967. "The Normative Roots of Economic Value." In S. Hook (ed.), *Human Values and Economic Policy*. New York: NYU Press.
- Lowe, Adolph. 1969. "Toward a Science of Political Economics." In R. Heilbroner (ed), *Economic Means and Social Ends*. Englewood Cliffs, N. J.: Prentice-Hall.

- Lowe, Adolph. 1971. "Is Present Day Higher Learning Relevant?" *Social Research*. 38: 563-580.
- Lowe, Adolph. 1988. *Has Freedom a Future?*. New York: Praeger.
- Lowe, Adolph. 1992. "A Self-Portrait." In P. Arestis and M. Sawyer (eds), *A Biographical Dictionary of Dissenting Economists*. Cheltenham, U.K.: Edward Elgar.
- Meadows, Donella. 1996. "Envisioning a Sustainable World." In R. Costanza, O. Segura, and J. Martinez-Alier (eds), *Getting Down to Earth*. Washington, D.C.: Island Press.
- Mills, C. Wright. 1959. *The Sociological Imagination*. New York: Oxford University Press.
- Norgaard, Richard B. 1989. "The Case for Methodological Pluralism." *Ecological Economics*. 1: 37-57.
- Ochs, Peter. 1993. "Charles Sanders Peirce." In D. R. Griffin (ed), *Founders of Constructive Postmodern Philosophy*. Albany: SUNY Press.
- Peirce, Charles Sanders. 1931-1960. *Collected Papers*. C. Hartshorne and P. Weiss (eds), Cambridge, MA: Harvard University Press.
- Polanyi, Michael. 1958. *Personal Knowledge*. Chicago: University of Chicago Press.
- Polya, Georges. 1957 [1945]. "How to Solve It." Princeton: Princeton University Press.
- Polya, Georges. 1984 [1948]. "On Patterns of Plausible Inference." In G.-C. Rota (ed), *Georges Polya: Collected Papers., Volume IV*. Cambridge, MA: MIT Press.
- Polya, Georges. 1984 [1958]. "On the Curriculum for Prospective High School Teachers." In G.-C. Rota (ed), *Georges Polya: Collected Papers., Volume IV*. Cambridge, MA: MIT Press.
- Polya, Georges. 1981 [1962]. *Mathematical Discovery*. New York: Wiley & Sons.
- Polya, Georges. 1984 [1971]. "Methodology or Heuristics, Strategy or Tactics?" In G.-C. Rota (ed), *Georges Polya: Collected Papers., Volume IV*. Cambridge, MA: MIT Press.
- Prugh, Thomas, Robert Costanza, John H. Cumberland, Herman E. Daly, Robert Goodland, and Richard B. Norgaard. 1995. *Natural Capital and Human Economic Survival*. Solomans, MD: International Society for Ecological Economics (ISEE Press).
- Prugh, Thomas, Robert Costanza, Herman E. Daly. 2000. *The Local Politics of Global Sustainability*. Washington, D.C.: Island Press.

Ryan, Grant, Philippe Moral, and Patrick Schembri. 1998. "Some Exploratory Scenarios Results." In S. Faucheux and M. O'Connor (eds), *Valuation for Sustainable Development*. Cheltenham, U.K.: Edward Elgar.

Schumpeter, Joseph. 1954. *History of Economic Analysis*. New York: Oxford University Press.

Vickers, Jeanne, ed. 1991 *Rethinking the Future: The Selected Correspondence of Geoffrey Vickers and Adolph Lowe*. New Brunswick, N. J.: Transactions Publishers.