The Economics of Sustainability

Holly Stallworth, Ph.D.
EPA/OPPE/OSEC
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I. The Conceptual Starting Point in Economics: Is there Something Missing Here?

Let's all go back in time to Economics 101. Maybe you were exposed to it in college or maybe in high school. Along about the first day or certainly the first week of class, the teacher puts this diagram on the board. Or maybe you read it in Chapter One of Samuelson. Anybody remember this *Circular Flow of Exchange between Firms and Households* diagram from Econ. 101?

This is the basic conceptual starting point for economics. Like all highly stylized diagrams, it's obviously an over-simplification, but, even considering that, is there something missing here? Where do all the inputs (raw materials and energy) from production come from? Where do all the waste outputs go? Unfortunately, this isn't an isolated instance where economics has a little blind spot. It' actually quite pervasive in economics to believe that the physical world is irrelevant to the economy. Before about the 1940's, the old production functions at least included "land" or "natural resources" as the third factor of production ("land" being a euphemism for all of the environment). With the publication of his classic 1947 textbook, Paul Samuelson dropped natural resources from the production function so that we have: Output Q = f [K, L] where K = capital and L= labor instead of the pre-1947 version where Q = f[K, L, N]. N was dropped. Why do you think Samuelson did that?

Let's try another diagram, one that hasn't really made its way into too many economics textbooks. In Figure 2, we see the economy as a subsystem of the global ecosystem -- an economy that draws matter and energy from the environment and returns it to the environment in the form of

waste. Herman Daly [currently at U. of MD wrote *Steady State Economics* in 1977, *For the Common Good* in 1989, and *Beyond Growth* in 1996] suggested that we expand our analytic vision to see our economy's dependency on the environment. The economy is not really a closed, isolated system; it is a sub-system of the biosphere, receiving and transforming the biosphere's matter and energy. The biosphere really serves as both *source & sink* for the economy. Daly called this one-way passage of matter & energy through the economic system *throughput.*

Daly has a rather graphic analogy for this blind spot in economics. By ignoring the environmental context for the economic process, this omission is, in Daly's word, "as if biology tried to understand animals only in terms of their circulatory system, with no recognition of their digestive tract" (Daly, 1988).

Throughput is the flow of matter-energy from nature's sources through the human economy. Nicholas Georgescu-Roegen (author of *The Entropy Law and the Economic Process*, 1971) first traced the nature of throughput to its origin in the second law of thermodynamics or the entropy law, the law of physics that Einstein considered the least likely to be overthrown. Georgescu-Roegen's work in linking the economic process with its physical, earthly basis extended the 1970 work by some RFF economists (Kneese, Ayres, and d'Arge) who had developed their "materials balance" framework showing that whatever goes in the economy as a material input eventually leaves as waste and pollution. Georgescu-Roegen's book took this one step further, showing that not only is there a "materials balance" between what enters and what leaves an economic process, *there is additionally an irreversable one-way change from available energy to unavailable energy.* Unlike matter, energy, once used, can never be recycled. It is this irreversibility -- this one-way flow -- that Georgescu-Roegen brought to our attention.

This word "sustainability" or "sustainable development" has become a big one. It has become a catch-all phrase that now refers to almost anything -- from recycling to planting trees to integrated policy analysis to sustained growth of output to the use of environmentally-adjusted national accounts or alternative indicators. The definition that everybody seems to like comes from the 1987 World Commission on Environment & Development:

"development that meets the needs of the present without compromising the ability of future generations to meet their economic needs." David Pearce, the British economist at the Center for Social and Economic Research on the Global Environment (CSERGE) in the UK, has collected these various definitions of sustainability in his 1989 book *Blueprint for a Green Economy*. We've all heard that many times, and it's that sense of intergenerational equity that we like, that has universal appeal. What I hope to do in this talk is introduce some of the issues involved in charting an economic direction that might achieve intergenerational equity or sustainability.

II. Sustainability for Economists Means Living Off Interest & Not Consuming Capital

If you ask the question, *what are we trying to sustain?* – almost everybody will agree that we're trying to sustain human welfare, that we're trying to leave our children at least as well off as we are. Defining those components of social welfare is always a subjective task – we could make up our own definition right now. Social welfare = f[quality & quantity of leisure time, quality of relationships, access to natural environments & recreational opportunities, housing, job satisfaction, sense of community, peace of mind, health, income, ...] No one can really write a perfect equation for social welfare, but no one's equation is really wrong either. Certainly, in almost everyone's equation, income would be included. It's an important, albeit incomplete, part of our welfare. Since we're talking about the economics of sustainability, let's focus on this economic component -- <u>income</u> – what it means to economists and what is required to sustain it.

For an economist, "income" might be something different than the size of your monthly check. We have to go back to J.R. Hicks, who in his 1946 book *Value & Capital*, defined *income as the maximum amount that can be consumed without eventual impoverishment*. It's kind of like interest on a savings account or the growth rate of a natural resource. In other words, if you have a $1000 in savings accruing 8% interest, you can only spend $80/year before you start dipping into capital and making yourself poorer. This is *Hicksian income* and *it's the defining characteristic of sustainability* because it is that amount which can be appropriated in perpetuity. That's

quite different from the size of your monthly paycheck which may bear little relation to "income" in the sense of what could be extracted from your capital stock without making yourself poorer.

All economists can agree on this, whether from the left or right sides of the spectrum: the main operational principle for sustainable economic activity is to keep capital intact. It's also called the *"constant capital" rule*. When we live beyond our income, we're left worse off. Unfortunately, agreement breaks down after this: that's why I want to talk to you about *strong* versus *weak sustainability*.

III. The Debate Over Strong vs. Weak Sustainability

First, we need some definitions of capital. What is capital? It's our stock of productive wealth -- that which generates a flow of services. There are at least three, maybe four, kinds of capital -- all spelled out for you in the Appendix.

Weak sustainability is about maintaining total capital stock (K = Km + Kn + Kh) without regard to proportions, with one kind of capital being substitutable for another. While it heeds the Hicksian call for limiting consumption to the "interest" or flow of services produced by that capital stock, weak sustainability aggregates all capital together. There is no "special role" for natural capital. This is the old neoclassical paradigm where Nature is just a sector of the economy for which other sectors can substitute. Weak sustainability advocates would acknowledge that natural capital is indeed depreciating (e.g. that we're losing arable land, topsoil, fisheries; we're depleting groundwater, polluting watersheds, etc.), but they subtract this depreciation from total investment in the economy.

Sometimes an equation can make this crystal clear. I apologize in advance to those of you who dislike math, but here's the equation for weak sustainability.

Shown in Figure 3, the so-called *genuine savings rule* developed by

Kirk Hamilton (Hamilton, 1994) relies upon the comparison between investment (in man-made capital) and the combined values of resource depletion and pollution. If $S > 0$, then investment in man-made capital is more than compensating for the losses of natural capital driven by resource depletion and pollution.

If $S > 0$, then the economy is weakly sustainable, given:

where S = savings; S = I - r - p
I = investment in man-made capital
r = resource depletion
p = total cost of pollution

Weak sustainability is achieved so long as we invest more than the combined depreciation of natural capital and man-made capital. $S > 0$ so long as investment exceeds depreciation of natural capital. Robert Solow of MIT is the most prominent advocate of weak sustainability in this country. According to the concept of weak sustainability, if you're running out of one kind of fish, you can just substitute another. (That's actually a quote from Robert Solow!) Our economies can convert most of the world's environment into man-made artifacts and we'd be as well off. A Starbucks coffee shop can substitute for a wetland. Beautiful music from a CD ROM can substitute for our disappearing songbirds. A more educated populace can substitute for a dwindling supply of arable land and fertile soil. It's all part of the everything-is-substitutable, everything-has-a-price world of neoclassical economics.

IV. Strong Sustainability = Environmental Sustainability $\Rightarrow$ $Kn_{(t+1)} \geq Kn_{(t)}$

Strong sustainability means treating natural capital (Kn) separately -- on the assumption that we cannot substitute man-made capital for it. To put it in layman's terms, strong sustainability rejects the idea that our built infrastructure adequately compensates future generations for the ecological losses entailed. While this may seem obvious to non-economists, man-made capital cannot, regardless of price, replace the services provided by

nature -- most especially life-support services, like protection from UV radiation, climate regulation, maintenance of soil fertility and the food chain, the storage, movement and purification of water, oxygen production and carbon sequestration, etc. Many economists (and other unknowing advocates of "weak" sustainability) are suggesting that any feature of the natural world can be traded for something else. In the strong sustainability view, nature cannot really be managed according to its marginal product. Its viability must be protected. If impaired, the unique services of ecological systems have no substitute; and irreversible harm or collapse can ensue and already has in many cases. The threat of irreversibility is enough for the strong sustainability advocate to favor a more *precautionary approach* to drawing the line on humankind's use of the environment. The precautionary principle says that where there are threats of serious or irreversible damage, we should not wait for full scientific consensus or monetized benefits to exceed monetized costs for the environment to be protected.

In addition to the overarching operation of the second law of thermodynamics, we have many other examples of irreversibility. There is no known way of removing greenhouse gases from the atmosphere or of restoring lost plant and animal species. Neither, at a certain point, will fishing boats be an adequate substitute for fish. Nor will sawmills function without their natural complement, the forest. The rain forest cannot be regenerated once deforestation erodes the soil and eliminates the seed. Although it is theoretically possible to tear up asphalt poured into parking lots and roads, it is highly unlikely that we'll ever reverse decisions to urbanize and suburbanize and bring back the open space, forests and farmlands we have lost to urban sprawl. For strong sustainability advocates, the specter of irreversibility puts much of the environmental debate on a different playing field. We should think much more carefully before closing off options to future generations.

We are loosely and abstractly calling all of these ecological life support assets and services "natural capital". Although not everyone will really like this term, the ecological economists first used it as a way of pointing out the tremendous wealth of the earth and its living systems. For the strong sustainability advocate, economic activity should be constrained by this over-arching ethic to protect "natural capital" or whatever term you might favor for the earth and its living systems.

Another variation on this theme is *carrying capacity*. To not deplete the natural capital that we leave to future societies, the scale (size) of the economy should be within carrying capacity. Carrying capacity is the uppermost limit on the number of species an ecosystem or habitat can sustain, given the supply and availability of nutrients.

How do we determine this? Fundamentally, we can use something like either "life cycle analysis" for an economy or "input-output analysis", focussing again on those two essential functions -- the source and sink functions of the environment. There are lots of ways to get at violations either on the source or sink side. I'll suggest a few here. *Ecological footprint analysis*, which originated in Canada, is an example of a carrying capacity calculation. A recent analysis by Asa Jansson of Sweden's Institute of Ecological Economics looked at the amount of wetlands that would be needed to assimilate the nitrogen emissions of the 85 million people in the Baltic Sea drainage basin. (Jansson, 1996) The answer comes out to be some 3-9 times the present available area of wetlands. Even more dramatically, on a planetary scale, another calculation involves looking at what happens when we extend our American lifestyle to the rest of the world's 5.7 billion people. We come up about 3 planets short.

There are at least two or three strong sustainability principles for guiding an economy to a scale that is within carrying capacity. The first has to do with the "source" of the economic process: *harvesting rates for renewable resources should not exceed regeneration rates.* This refers simply to the pressure on resources like over-foresting, over-fishing, over-grazing, depleting groundwater aquifers faster than their recharge rates, etc.

Some ecologists have objected to the single-minded focus on yielding one output from an ecosystem -- whether it is fish or forests; and that is because MSY has always been more of a quantitative measure. More and more, we see ecological economics interpreting sustainability in broader, qualitative terms: in terms of an ecosystem's health, its resilience, its ability to withstand stress, so I have added in Figure 5 a sustainability principle that gets to the more qualitative dimension of ecosystem health. The authors of this principle are part of an educational group in Sweden called "The Natural Step". In their words:

The physical basis for the productivity and diversity of nature must not be systematically deteriorated. This means: the productive surfaces of nature must not be diminished in quality or quantity ... because our health and prosperity depend on the capacity of nature to reconcentrate and restructure wastes into resources. (Robert, Holmberg and Eriksson, 1994)

A recent article in *Ecological Economics* by Fraser Smith (1996) confirmed this affinity between ecosystem health and sustainability, suggesting that biodiversity or "species richness" was the best surrogate indicator we have for ecosystem health.

At the other end of the economy's digestive system, the strong sustainability principle is: *waste emissions should not exceed the assimilative capacity of the environment.* This is the "sink function" discussed earlier. We're finding that Thomas Malthus' premonition of limits to growth based on finite inputs may need to be restated. What is posing limits to human activity is more the availability of "sinks" or ecosystem functions to assimilate our emissions. "Sink" functions have become much more the limiting factor in economic growth – one perhaps not yet contemplated when the Meadows first started this debate with *The Limits to Growth* (1973?).

For decades, we've had lots of measures of unsustainability -- the build-up of toxic emissions, acid rain, greenhouse gases, virtually all water pollution – whether chemical or non-point source. All of this information tells us about unsustainability. These are all the chemical and physical stresses on ecological systems that we've been studying here at EPA for years. I sometimes feel distress when I hear someone talk about sustainability as if it were a new paradigm that requires a whole new set of indicators when we've had much of this information – at least information about unsustainability -- for years. Sustainable development may not require its own new set of indicators so much as it may require paying attention to where we already know we've exceeded the assimilative capacity of the environment.

V. Framing Questions for Communities: Going from the Macro Vision of Sustainability to Micro Directions

Georgescu-Roegen has said that our economic choices should not be based on the principle of maximizing utility, but rather on minimizing regret. A basis of the growing popularity over "sustainability" is a widening recognition that macro-indicators like GNP are completely divorced from biological and physical planetary realities. Yet, we continue to witness macroeconomy policy being made in relation to this gross measure of market activity, of money changing hands.

The "green critique" of GNP as a measure of economic welfare is quite powerful -- important enough to merit a little discussion here. Let me digress for a bit on this subject of environmentally adjusted national accounts (EANA's). Some of what you saw in the equation for weak sustainability (the terms r and p) refer to the aggregate monetized values for environmental degradation. It has long been suggested that the cost of our environmental ills should be subtracted from our measures of economic welfare. Many environmental economists are working on the full integration of environmental costs and benefits into the national income accounts themselves, particularly given that GNP is used as a target of economic policy. The best and most recent example of this kind of alternative indicator can be seen in Figure 4 which depicts the *Genuine Progress Indicator*, GPI, for the years 1950-95. GPI attempts to add up the goods and services consumed in the economy whether or not money changes hands. Thus it adds the value of household work and parenting and volunteer work. Then it subtracts out the three categories of expense: defensive expenditures (which compensate for past costs), social costs, and the depreciation of environmental assets.

As you can see from the way GPI has been taking a nosedive lately, we've got some huge externalities operating in our economy. Top cope with some of this, at least the environmental costs, ecological economists are calling for "ecological tax reform", shifting the tax base away from labor-derived income and investment-derived income toward taxes on activities

we want to discourage: resource extraction, pollution, waste in packaging, etc. Again, here's an area where economists of all stripes agree: building environmental costs right into the price system would instill enormous prudence in our production and consumption decisions. Your after-tax income would be much more a function of the energy that you consume, the ecological costs of the products that you buy, and the amount of waste you discard. Unfortunately, concepts such as these still receive almost no attention from the national media or political leaders.

That's what strong sustainability might mean on the national scene. Let's talk about the local level. Today's local economies are no longer really "local" and they're certainly not "closed loop" because they're increasingly enmeshed in the larger regional, national and international economies. As a result, it is very difficult to assess the "sustainability" of production and consumption processes when sources and sinks related to that local area span the entire globe. Just think about what you had for breakfast or what you're wearing. Chances are, it came from pretty far away.

The problem of assessing sustainability at the local level -- in light of the imports and exports that take place -- is, in fact, nearly intractable. Frankly, it would take an economy as isolated as a tribal community in outer Mongolia to trace biophysical flows of materials, energy and water from *source* to *sink* -- from the beginnings of productions to the tail endings of consumption.

It's my assessment that all of this talk about a Sustainable Seattle, a Sustainable Chattanooga, or a Sustainable San Francisco or a Sustainable Charlottesville really kind of takes liberties with the sustainability notion and in so doing, undercuts ultimate achievement of a more environmentally-based sustainability. Not to suggest that changes made by these groups flying under the banner of sustainable development aren't positive and encouraging and directionally correct. Nor am I voting against incremental progress. It is rather to say that the admirable steps they have taken are just the beginning, not the end, of the path to sustainability . For the strong sustainability advocates, such as myself, the meaning of sustainability has been watered down a bit too much for my taste. Herman Daly's recently released book *Beyond Growth* (1996) addresses precisely this issue.

Absent this total picture of biophysical flows from source to sink in a local economy, we will have to make do with what we already know is unsustainable and what we know is directionally correct. Let me suggest some principles or directions here that seem to be consistent with the economists' injunction to "live off interest" and "not consume capital." There are at least two principles, probably many more, but these two I'll offer as intuition for how to channel economic directions at the local level.

Eco-cyclical processes

"Closing the loop" in the economy, as Barry Commoner first suggested over two decades ago, provides some directional guidance at the local level. More recently, a Swedish environmental group called "The Natural Step", formed in 1989, is centering in sustainability educational program around what they call "ecocyclical processes" or replacing linear processes with cyclical ones. Eco-logic means using nature as the prototype for how the economy should function. In nature's no-waste economy, each "waste" from one process becomes the raw material for another process.

At least three fields of study exemplify this eco-cyclical approach of capitalizing on synergies gained from designing agricultural and industrial processes to mimic ecosystem processes: agroecology and industrial ecology and eco-forestry. Here's a few examples: turning livestock residue into fertilizer, using crop residue as an input into another agricultural or industrial process, using game ranching rather than cattle ranching in tropical ecosystems, using integrated pest management in agriculture rather than chemicals, using constructed wetlands for wastewater processing (Colby, 1992).

If you look at Figure 2, you'll see the arrow that goes from waste outputs back to productive inputs. The "waste equals food" principles gives us an enormous amount of guidance toward defining that part of our productive world that is truly "interest" or "income" or "flow" as opposed to "stock" -- that part which we can consume without eventually impoverishing ourselves or our descendents. Paul Hawken, author of the 1993 book *The Ecology of Commerce*, calls it "the restorative economy" -- meaning one that works in symbiosis with natural systems of production and consumption.

Transitioning away from fossil fuels toward plant matter

Most of the energy flow through our economy is based on stored carbon -- exhaustible fuels, the use of which is, by definition, unsustainable. While Daly has thought about the ethics and pace of transitioning away from exhaustible fuel sources, others have specified ways in which to convert to renewable energy sources. Amory Lovins may be the most famous advocate of this "soft path" he described some twenty years ago. Most recently, we have the work of David Morris, author of *The Carbohydrate Economy: Making Chemicals and Industrial Materials from Plant Matter* (1992) who describes a number of bioprocessing techniques that enable the use of plant materials (like hemp or whey) to be used as industrial fuels, chemicals, electricity, consumer products and sometimes food. The ultimate goal of this approach is to use energy at a rate no great than the rate that solar energy falls upon the planet.

Shorter Supply Lines

The average food product travels 1300 miles from where it is grown to where it is consumed (Daly, 1996). We have good reason to believe that a more sustainable economy is a more localized, decentralized economy: one with shorter supply lines where inputs to production are drawn from an area close to the site of production and to the locus of consumption. Externalities of consumption, frankly, are much hard to get a handle on. Since most of what we consume, now, is imported, we know much less about the environmental costs imposed by those products. Our cars, our clothes and our food are all mostly brought from afar. Most local governments are simply not willing to address consumption externalities in a serious way: with heavy energy taxes to discourage energy use, to impose product taxes based on packaging. Unfortunately, much of our consumption is tied to prices that are set at the national & global levels.

It is well known that locally-produced goods and services have one prime advantage over goods imported from other places: buyers know more about what they're getting, where it came from, and how it was produced. Consequently, both producers and consumers are likely to take

more responsibility for their choices, knowing, for example, that our local corn crop may be threatened by urban development or that value could be added by using the corn husks in energy production. When the costs of production are borne close to where those products are consumed, people are more likely to act responsibly.

Current transportation prices come nowhere near the level of reflecting the full environmental and social costs of production. A more self-reliant, localized economy is to reduce environmentally costly transportation of goods between communities, regions, states and nations. Almost all forms of transportation are subsidized by the federal government either directly or through the tax mechanism: our roads, our trucking system, our freight trains, and our air transport. Consequently strawberries & lettuce shipped in from California do not carry a price that reflects those environmental and social costs of transportation (not to mention water and other farm subsidies). As long as these subsidies predominate and prices do not reflect full costs, we cannot know whether the comparative advantages of trading outweigh the environmental costs of transport. Without negating the advantages of trade altogether, let us not achieve our "sustainability" by simply removing from sight the side-effects of production: for example, by importing our consumer goods and exporting our waste.

Interim Strategies and Development Options in a Second-Best World: Value-Added, Nature Tourism, and the Service Sector

In some cases in our community-based work, we are called upon to mediate the immediate and pressing conflicts between economic direction and environmental protection. Local communities are not looking to soon become "closed loop", to change their energy supplies to more renewable methods or to shorten their supply lines. For the time being, they need development options that simply bring money into their area to create or maintain jobs, to provide tax revenues to support local schools and other governmental functions. Several economists and non-profit groups are provided good advice along these lines.

In many beautiful and scenic spots in the West, the Wilderness Society's economist Ray Rasker, author of their workbook *Measuring*

Change in Rural Communities, is working with communities who have traditionally raised money by mining or logging. Rasker conducts a workshop for local residents, business people and government officials that profiles that community's economy using recent data available from the Bureau of Census. Typically, as local economies mimic the national pattern of an increasing workforce employed in the "service sector", the curves that are plotted for that community show job growth in "service sector" or information-based firms with jobs declining in the extractive sector. Thus communities find they have some alternative to mining or logging. Oftentimes, nature tourism or wilderness based recreation is a way of preserving the best of a bioregion while providing income and jobs to local residents. This allows communities to do a better job of controlling certain production externalities, although consumption externalities go unchecked.

Similarly, Tom Power, a University of Montana economist and author of *Lost Landscapes and Failed Economies* (1996) has advocated a strategy of attracting footloose firms (those that can operate by modem) or footloose income (retirees whose monthly checks follow them wherever they go), as an alternative to unsustainable logging, or extraction of non-renewable resources.

Thus, while retirees may not need to cut the beautiful wilds of Montana or Oregon or Idaho, they will continue to buy goods from the global economy that are produced without much concern for resource renewal, recycling, ecological disruption, etc. While retirees or computer professionals may enjoy their scenic view and fight mightily against local logging, they will continue to drive energy-inefficient cars made of non-renewable resources; they will live in houses that will consume electricity that may be produced by destroying the salmon runs of a previously wild and scenic river; and they most definitely will consume food that is produced by our chemical and fertilizer dependent system of agribusiness, where soil erosion and run-off are as much an output of the economic process as corn and wheat.

These local development schemes can certainly forestall a mode of production that might have devastating environmental impacts, BUT let me be clear. Whether it is ecotourism, wilderness-based recreation, footloose income or footloose firms, none of these strategies really comes to grips with the complete biophysical and ecological picture of sustainability that we

need to hold in mind. That is why I have titled this section *Interim Strategies and Development Options in a Second-Best World*. In some cases, these development strategies might be more akin to putting a finger in the dike -- a second-best choice utilized when facing a much worse outcome. While acknowledging the value of these strategies in particular places and particular circumstances, let us still recognize the inherent contradiction in these efforts: namely that the local "sustainability" effort depends on an unsustainable larger economy.

Concluding Thoughts

Those of you in this room may be well aware that EPA has recently recognized that our historical mission to control pollution through national legislative mandates will fall short of the full sustainability challenge and this extraordinary gamut of environmental problems driven by economic forces. In the Office of Sustainable Ecosystems and Communities at Headquarters and at many other such offices throughout the Regions, some of us are charged with assisting communities interested in pursuing "sustainability" or one of its various dimensions. It is my belief that we have plenty of work to do and plenty of ways in which to do it.

Although much of what I have said may sound overwhelming, I don't want to leave you depressed. I have hope that the seeds of an ecologically saner economy are available, and – in some cases – are planted. There are plenty of ideas for "greening" the economy, perhaps more than we have the political will to carry out. I'm hoping that I can do my part by helping to shape our thinking at EPA about economics and the environment.

Definitions and Abbreviations

Assimilative capacity -- the ability of the biophysical world (air, water and soil media) to absorb the waste products generated by economic activity

Capital -- the set of all physical things capable of satisfying human wants; a stock that yield a flow of services; abbreviated as K.

Defensive expenditures -- expenditures which compensate for past costs or the unwanted side effects of production; an expenditure regrettably made necessary by some other act of production.

Externality -- an activity that has unintended consequences for others and is not reflected in the price system.

GNP -- Gross Domestic Product; total dollar value of the nation's output

GPI -- Genuine Progress Indicator; a revised measure of the nation's well being that accounts for defensive expenditures, social costs and the depreciation of environmental assets and natural resources.

Hicksian income -- that which can be consumed without depleting capital

Investment -- capital formation; addition to stock of productive wealth; abbreviated as I.

Natural capital -- biodiversity, wetlands, fossil fuels, minerals, rivers, forests, etc.; the non-produced or natural stock that yields a flow of services; abbreviated as Kn.

Neoclassical economics -- the school of economic thought that translated the ideas of the classical economic theorists (e.g. Adam Smith and David Ricardo) into a mathematical calculus based on optimizing or achieving a specified goal at minimum cost (and maximum efficiency). Neoclassical theory focuses on allocation or achieving the most efficient distribution of scarce resources.

Service -- satisfaction of wants and needs

Throughput -- physical flow of matter and energy from nature's sources through the human economy and back to nature's sinks

NNP -- net national product; equal to GNP minus depreciation of man-made capital

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