Human Economics: putting humanity and the environment before profit

FRANK ROTERING

In the first half of 2003 about fifty Feasta members engaged in a vigorous internet discussion on Human Economics, Frank Rotering's proposed alternative to standard economic theory. Frank's aim was to develop an economic system that maximised human well-being and natural sustainability rather than profits and incomes growth and the paper that sparked the discussion can be found on the Feasta website together with all the e-mails exchanged during the discussion.

The version of Frank's theory we are printing here is the one that emerged as a result of the e-mail exchanges. It is followed by a commentary on whether it is possible to measure health in a way that could allow its maximisation to become the main goal of economic policy by Douglas McCullough, a health economist at the University of Ulster.

INTRODUCTION

Before offering a summary of human economics, let me provide two reasons why I believe that Feasta, and the sustainability movement generally, requires such a theory. First, some Feasta members tend to believe in a pragmatic form of activism based on immediate perceptions and intuitive strategies. For example, in the discussion, several participants strongly resisted the development of a new economic theory because the defects of the current system were obvious and could be directly addressed.

Many abuses of the current system are indeed glaring. No theory is required to reject profligate energy consumption and the resultant greenhouse gas emissions. Common sense alone refutes endless growth and rampant habitat destruction. Beneath the readily-apparent surface, however, lie subtle realities and counterintuitive solutions and an economic theory would force us to derive our policy prescriptions from first principles and systematic logic. It would enable us to confirm our correct notions and to repudiate our errors.

Second, our economic terminology is currently a mess. We frequently lack terms for ideas we cherish and use ill-conceived terms that subvert our purposes. For example, we have no term that refers to the injuries suffered by workers in production. Standard economics sees the world from the capitalist perspective and therefore ignores this. Without the excuse of ideology, so do we.

A prime example of an ill-conceived term is that ubiquitous oxymoron, "natural capital". Capital is an accumulation of monetary assets that finances capitalist production. It is the product of humanity's social relations, which are distinct from natural processes. "Natural capital" is the conflation of two separate realms and an invitation to deep confusion.

The development of a new economic theory would compel us to produce the terms we lack and to retire those that mislead us. Nothing would contribute more to the clarification of our ideas and the effectiveness of our actions.

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What follows is a summary of human economics. It was written after the website paper and reflects some modifications to my thinking, in part due to the group discussion. If you are new to economic thinking and find yourself struggling with marginal quantities and similar concepts below, read part 2 of my paper, a primer on economic analysis, on the Feasta website (http://www.feasta.org/documents/papers/rotering2.htm). If you want more details on the human and ecological frameworks, see parts 3 and 4.

One final point before I begin. An economic theory is an immense undertaking, far beyond the capacity of a single person. What I present here is a bare beginning, requiring extensive correction and development by numerous progressive thinkers.

A. THE STRUCTURE OF HUMAN ECONOMICS

Human economics is, first of all, a theory - that is, a set of ideas that can be applied to analysis. It is not a set of policy prescriptions. However, human economics is not a neutral theory. It is based on an objective that leads to policies favouring humanity over capital and environmental sustainability over growth and collapse.

The objective of human economics is to formulate economic concepts and analytical tools that permit the maximization of human well-being subject to ecological constraints.

This definition places humanity and the environment on a roughly even footing. We must maximize human well-being AND safeguard the environment. If we don't do the first, our economy has no rational human purpose. If we don't do the second, we undermine future human well-being and destroy non-human species. The fundamental challenge is to balance these sometimes conflicting objectives in a rational manner.

This paper will therefore discuss three things: the human objective for an economy, the constraints imposed on our economic activities by the environment, and the economy itself.

Let me start with the objective. Maximization of human well-being is a reasonable general goal, but it is clearly insufficient for economic analysis. What is meant by human well-being? How do we define the value of what we produce and the cost we incur in producing it? How much of an output is "enough"?

In all but the simplest economies, the answers to such questions are not readily apparent and can only be addressed with a set of conceptual tools. In human economics these constitute the human framework described in some detail below.

Next are constraints. From the economic perspective, the environment consists of inorganic resource stocks, organic resource flows, and waste flows. These stocks and flows cannot be analyzed with the same value and cost concepts used in the human framework. The human and natural realms, while ineluctably linked, are in separate conceptual domains, and require separate theoretical treatments. The terms and tools used to address environmental constraints constitute the ecological framework. This is also addressed in some detail below.

Last is the economy itself. The concepts required here, because they address the actual functioning of an economic system, are called the functional framework. There is an important distinction between this framework and the first two. While there is only one humanity and one environment, there are many existing and potential economic systems.

This implies that we can formulate a single human framework and a single ecological framework, but that multiple functional frameworks are required. In human economics I have addressed only capitalism, the globe's dominant economic organization in the current historical period. This topic is beyond the scope of the present summary.

In brief: human economics separately tackles the ends, constraints, and means of economic activities. Ends are addressed in the human framework, which can be used to define a humane economy. Constraints are addressed in

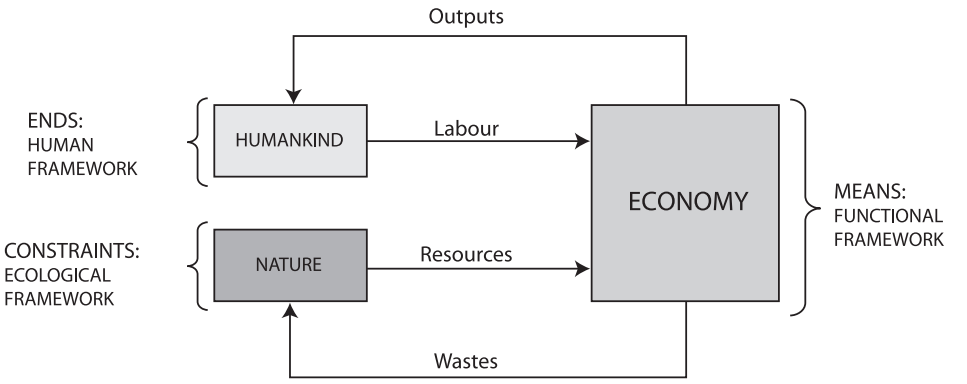

Figure 1: *Structure of human economics*

the ecological framework, which can be used to define a sustainable economy. Means are addressed in the functional frameworks, which can be used to describe actual economic systems. This structure is depicted in Figure 1.

B. GRAPHS AND RIGOUR

Except for the relationship between humanity and nature, no topic was debated more fervently in the discussion group than my attempt to inject rigour into human economics, specifically my use of graphs. The group's main objection was that the quantities I describe have never been measured, and that my graphs are therefore meaningless. This is a misconception which must be addressed before I proceed.

Graphs can be divided into two categories: those that express known quantitative relationships and those that express general conceptual relationships.

Open in front of me is a physics text, showing a graph that relates the force on an automobile as a function of time during an impact. Force is on the vertical axis, in Newtons. Time is on the horizontal axis, in seconds. The curve traces the force on a Mercedes-Benz during the 120 milliseconds of a crash. This graph is based on actual measurements and therefore expresses a known quantitative relationship.

I am now looking at the intriguing book *Rare Earth: Why Complex Life Is Uncommon in the Universe*. On page 172 the two authors, professors of geology and astronomy, show a graph that relates species diversity to mass extinction events. Diversity is on the vertical axis, without units. Mass extinction events is on the horizontal axis, also without units. There are two curves, depicting two possible relationships between the variables. These curves are not based on any measurements because none are available. Nevertheless, they accurately express general conceptual relationships and they are useful in clarifying the authors' meaning.

So long as the underlying ideas are sound, conceptual curves can accurately depict broad relationships and permit the analyst to draw general conclusions. Such curves are frequently indispensable in the early stages of scientific development. Before we can measure we must conceptualize the quantities to be measured. Before we can construct a thermometer we must understand that there is heat and cold.

Given that human economics is in its infancy, all my graphs express general conceptual relationships. The test of these graphs is not whether the quantities have been measured, but whether I base them on sound concepts and whether the relationships between the curves are correct.

I should add that, while I'm interested in detailed quantification in the long term, my immediate objective in using graphs is to express my thoughts with the greatest possible clarity and to expose them to the sternest possible scrutiny. It's easy to hide sloppy logic in a profusion of words. Graphs enforce tight definitions and strict relationships, allowing a sharp critic to quickly expose fallacies.

C. THE HUMAN FRAMEWORK

1. THE STANDARD OF VALUE AND COST

Value is what human beings need or desire in an output, while cost is the sacrifice we must make to obtain this value. Among the most fundamental questions for any economic theory are:

a) How do we judge needs and desires? That is, what is the standard of value?
b) How do we judge sacrifices? That is, what is the standard of cost?

We might, for instance, decide that population is the appropriate standard of value. Consumption that results in a higher population would then be preferred to consumption that results in a lower population. We might decide that energy use is the appropriate standard of cost. Production that uses less energy would then be preferred to production that uses more.

This example uses separate standards for value and cost, but this is not necessary. We might decide to use self-reported happiness for both. Our aim would then be to consume so as to gain the most happiness and to produce so as to lose the least happiness.

Standard economics uses a single standard - subjective wants expressed in money - for value and cost, and a single standard is required in the human framework as well. If we try to apply separate standards we encounter insurmountable analytical hurdles.

The next question is: should this single standard be subjective or objective? I find a subjective standard, such as personal wants, to be unacceptable for the following reasons:

1. Subjective needs and wants can only be measured by something external, such as money. If money is used, then demand means "effective demand" - it must be backed by cash. A penniless person dying of thirst has, in this sense, no demand for water. If water is not free, and if a good Samaritan does not appear, this person will perish. Money - or whatever expresses subjective desires - masks our real needs and wants.
2. A subjective standard makes interpersonal comparisons impossible. The internal state of one person cannot be compared with that of another. This leads to gross economic injustices. For example, it places a poor person's desperate need for a necessity on the same plane as a rich person's frivolous desire for a luxury. It fails to differentiate between widely divergent ethical situations.
3. Subjective demand can be powerfully shaped by social influences, such as advertising, media images, peer pressure, and the like. So-called subjective demand is frequently nothing but the implanted whims of corporate marketing departments.

The human framework thus requires a single, objective standard of value and cost. Following are the key considerations to determine what this standard should be:

> Human economics seeks to maximize human well-being. The standard should therefore be intimately tied to the survival and flourishing of human beings.
> To be useful as a set of analytical tools, the human framework should be as rigorous as its subject matter permits. The standard should therefore be quantifiable and allow for at least a rough unit of measurement.
> Human beings interact with an economy in three main ways: directly through labour and consumption, and indirectly through the economy's impact on the environment. The standard must be capable of measuring all three interactions.

A standard that meets all these criteria is human health. It is objective, is intimately associated with well-being, permits quantification, and is capable of measuring all three economic interactions.

Stated more fully, the standard of value and cost in the human framework is human life and the physical, mental, and emotional health of human beings. Thus, if an output supports human life and increases health, it has value. If production destroys human life and decreases health, it incurs cost.

2. THE HEALTH UNIT

While the standard of value and cost is adequate as a general criterion, it is too broad to serve as a standard of measurement. That is, it appears impossible to define a measurement unit that embraces both life and a broad conception of health.

My solution here is to use physical health as an index, or indicator, of life and overall health. Physical health implies life and is directly measurable. Recent research has found it to be strongly influenced by mental and emotional factors. Stress, worry, and loneliness all have physical symptoms. Poverty has recently been linked to obesity. Even joy and laughter are expressed at the physical level. Physical health is probably the most accurate single indicator of overall human well-being available to us.

It is not difficult to see how a unit of measurement can be established on the basis of physical health (simply "health" from here on). The zero point in the measurement of health is the state where a representative person is minimally alive. From this point, any reduction in health will result in death. At the other extreme is the currently attainable peak of health. This means complete freedom from disease and injury, and the greatest possible vigour, strength, flexibility, sensory acuity, stamina, and so forth.

This continuum of health states, from minimal life to its currently achievable peak, can be divided into equal increments. The details of such a division must be left to health experts, but there is no obstacle to it in principle.

A rudimentary example of such a scale already exists for newborns - the APGAR score. When a baby is born, a doctor can assign 0-2 points for each of muscle tone, pulse, reflex, skin colour, and respiration. The total score tells the medical team if the baby is healthy, warrants some attention, or requires immediate resuscitation. Extending this scheme appears relatively straightforward.

The other essential aspect of health is time. An increment in health that lasts for 20 days is 10 times greater than the same increment lasting for two days. For example, an apple might increase health by ten increments for three days. A house might increase health by eight increments for 50 years. Although the apple has the greater short-term health effect, the house has a much greater long-term impact.

In brief, the health unit can be defined in terms of a specified increment along the physical health continuum, for a specified period of time. To continue the conceptual development, I presume below that such a unit has been operationally defined.

3. EVALUATING FINAL OUTPUTS: INTRINSIC VALUE

My use of the term **intrinsic value** derives from John Ruskin, a 19th century social theorist and critic of art and architecture. Ruskin defined intrinsic value as ".. the absolute power of anything to support life." He insisted that this power is objective and thus independent of human desire and judgment.

Based on the standard of value and cost developed above, I define intrinsic value as the capacity of a final output to support human life or to increase overall human health. If the output has the opposite effect - if it destroys life or decreases health, then its intrinsic value is a negative quantity.

The key word here is "capacity". Earlier I stated that an apple might increase health by ten health increments for three days. If we define the health unit as one health increment for one day, then an apple contains 30 health units of intrinsic value.

An apple, however, can be thrown away or allowed to spoil. The 30 units constitute only a potential, which may or may not be realized. The apple has to be eaten, while fresh, by someone who can fully assimilate its nutrients. Only then will the 30 units of potential health be transformed into 30 units of actual health.

Note that the discussion here is about final outputs - objects and services that are directly consumed, such as food, furniture, and haircuts. These outputs must be distinguished from intermediate outputs such as raw materials, buildings, tools, and machinery. While intermediate outputs are essential to production, they are not directly consumed and do not, themselves, contribute to human life and health. They therefore fall outside the definition of intrinsic value.

The intrinsic value of an output is a constant quantity. No matter how many apples are produced, it is presumably always possible for someone to consume the last one so as to extract its full health potential.

Intrinsic value refers to the potential health flowing from an output during its entire lifespan. If a house is expected to last 50 years, and if it will deliver an average of 100,000 health units per year, then the intrinsic value of the house is 5,000,000 health units. The same principle holds for effectual value and input cost, which are discussed below.

To summarize, intrinsic value can be positive or negative, and is measured in health units. It is used in the human framework to judge the quality of an economy's outputs.

4. EVALUATING CONSUMPTION: EFFECTUAL VALUE

Whereas intrinsic value is a capacity, **effectual value** is the realization of this capacity through consumption. It expresses the degree to which the conversion of potential to actual health has been successful.

If the apple mentioned above is consumed in such a manner that all its intrinsic value is realized, the outcome is 30 health units of effectual value. If half the apple is eaten and the rest discarded, the outcome is 15 units. If the apple is left to rot, the result is zero units.

Like intrinsic value, effectual value can be positive or negative, and is measured in health units. Unlike intrinsic value, it tends to decrease at the margin as more of an output is consumed.

There are several reasons why effectual value tends to decrease. An output is generally applied first to highly valued uses, and then progressively to less valued uses. Clean water, for instance, is first used to slake thirst, then to cook food, and finally to water lawns and wash cars. As the available quantity of clean water increases, the health benefits of the last increment tends to decline.

Another reason is satiation: one apple a day produces excellent health benefits, but the body can absorb only a finite quantity of an apple's nutrients. As more apples are eaten, the health gains of the last one will steadily diminish. Eating too many apples will eventually decrease health, which is why marginal effectual value becomes negative in Figure 2.

In brief, effectual value is used in the human framework to judge consumption. It answers the question: given a certain amount of intrinsic value created in production, how effectively is this converted into real health benefits?

5. THE ECONOMY AND NATURE

The standard proposed above pertains to human beings exclusively. It is inapplicable to the natural world outside our bodies. Humanity is the realm of value and cost, while nature is the realm of physical stocks and flows.

A key conceptual problem is how to bridge this divide. If production destroys an environmental asset we cannot refer to this as a cost without self-contradiction. Yet we must account for the negative impact if we are to respect ecological constraints. I have adopted the following approach.

First, I make two distinctions:

1. **Between marginal effects and threshold effects.** When a lake is initially polluted, the pollutants affect human health incrementally by contaminating fish and poisoning drinking and swimming water. These are marginal effects. Beyond a critical point, the lake's ecosystem will collapse. This is a threshold effect.
2. **Between marginal effects that impact human life and health, and those that do not.** The latter include environmental changes that some people may find aesthetically or spiritually destructive, but that do not have health consequences.

Second, based on these distinctions, I divide the natural effects of production into three categories:

1. Marginal effects that impact human life and health
2. Marginal effects that do not impact human life and health
3. Threshold effects

The first category can be addressed with the concept of natural cost, defined below. The second category falls outside the scope of the standard of value and cost, which means such effects cannot be analyzed in the human framework. The third category cannot be addressed with marginal analysis in principle because a threshold entails discontinuity. An analytical approach to threshold effects is offered in the ecological framework.

The fact that the second category falls outside the scope of the human framework is not a weakness, but reflects the intentional limits placed on the framework. As indicated in part 1 of my paper, an economic theory should not overextend itself. Many issues are not primarily economic, but rather political, ethical, or spiritual. Economics is the study of production, exchange, and consumption. It should fully address these, but if it attempts to do more it will blur its concepts and impair its analytical acuity.

6. EVALUATING PRODUCTION: COSTS

When inputs are used up in production, two different things are sacrificed:

1. The possibility of employing the same inputs for any other production
2. The impacts on the participants in production - the human beings who provide the labour and the natural facilities that furnish the resources and receive the wastes

Among the most blatant ideological distortions in standard economics is the reduction of both types of sacrifices to the first. The second type is ignored, thus sweeping the potential destruction of people and nature under the rug. This ethically bankrupt combination is called opportunity cost.

Despite its misuse by standard economics, opportunity cost is not a false concept, but rather a limited one. The human framework accepts the concept within its proper scope. In the human framework, the **opportunity cost** of using an input in production is the intrinsic value of the best alternative output to which that input could have been applied. By minimizing opportunity cost in production we allocate labour and natural facilities to the outputs that maximize potential health benefits.

The second type of sacrifice is called **input cost**, defined as the direct and indirect effects of production on human life and health. When these effects are direct - through labour - they are called **labour cost**. When they are indirect - through environmental changes associated with production - they are called **natural cost**. The sum of labour cost and natural cost is the input cost of production.

Labour can cause both positive and negative health effects. Labour cost is positive when labour causes excessive fatigue, debilitating stress, injuries, disease, or death. It is negative when labour increases strength, stamina, vigour, etc.

Note the potential confusion here. Cost - meaning positive cost - refers to the sacrifice human beings make in obtaining value. A positive cost is therefore a bad thing - it implies a decrease in life and health. Conversely, a negative cost is a good thing - it implies an increase in life health. Please take this inversion into account when you examine Figure 2.

Natural cost can also be positive or negative, and the same inversion applies as for labour cost. Natural cost is positive when production fouls the environment and destroys habitat in such a manner that human health is adversely affected. It is negative when production creates a cleaner or more habitable environment, resulting in increased human health.

Both labour cost and natural cost are assumed to increase at the margin. This is consistent with our experience: as labour time increases, fatigue, stress, and injuries will all tend to rise; as pollution accumulates, its health effects will steadily worsen.

7. OPTIMUM QUANTITY FOR A FINAL OUTPUT

The four quantities discussed above can now be graphed to determine, in a general conceptual sense, the optimum quantity for a final output. This is depicted in Figure 2.

The optimization rule is that quantity should increase until the rising cost of production (input cost) exceeds the falling value of consumption (effectual value). This occurs at quantity Q*, which is therefore the optimum quantity for the final output.

At Q* human beings gain the maximum possible health - represented by the shaded area at left. If less is produced, this area will shrink. If more is produced, losses are incurred, as shown by the shaded area at right. These losses must be subtracted from the gains, thus reducing net gains.

It is important to note that Q* is an optimum quantity, not just a maximum quantity. We must decrease output to Q* if it is currently more, but we must not fail to increase output to Q* if it is currently less. I underscore this because many outputs are underproduced, not overproduced. This is particularly true for those that address the needs of the poor.

The optimization shown here is based on the current value and cost curves, but an economy can - and frequently should - be reorganized to change these. If outputs are distributed more equally and fewer are wasted, the effectual value curve will move up. This will increase the optimum output quantity.

Similarly, if fewer workers die and suffer injuries in production, and if reduced pollution improves health, the input cost curve will move down. This will again increase the optimum output quantity.

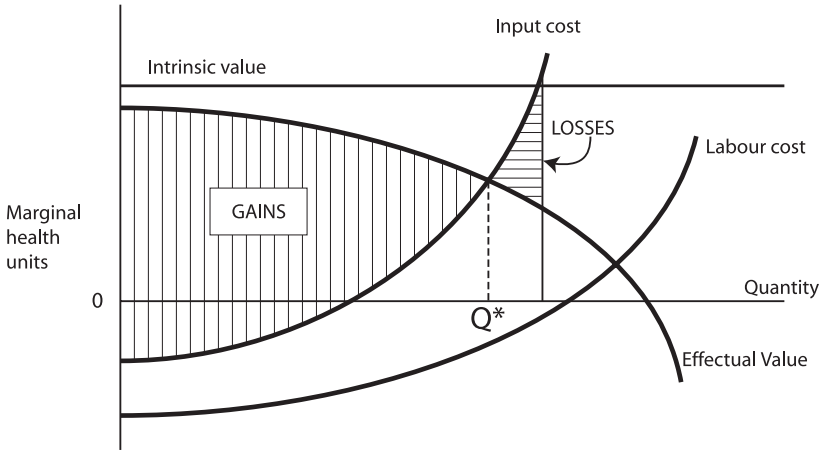

Figure 2: *Optimum quantity for a final output*

The optimum quantity of an output is therefore not fixed, but shifts according to the conditions of production and consumption. To improve an economy, we can choose to move output quantity toward the optimum, change the conditions, or both.

One more point: if input cost is equal to or greater than effectual value when quantity is zero, then this output should not be produced at all.

An apparent limitation of the above method is that it applies exclusively to final outputs. This leaves open an important question: what is the optimum quantity for an intermediate output such as a raw material, lorry (truck), or accounting service?

As stated, intermediate outputs have no intrinsic value. We can consume the food transported by a lorry, but not the lorry itself. The "value" of an intermediate output is therefore a derived quantity - it depends on the intrinsic value of the final outputs it helps produce. If a community needs 20 lorries to transport the optimum quantity of its food from farm to shop, then the optimum quantity of its food-transporting lorries is 20.

In general: The optimum quantity of an intermediate output is the minimum required to produce the optimum quantities of all the final outputs with which it is associated.

If the above is correct, we have a broad conceptual approach for determining optimum quantities of both final and intermediate outputs. This answers two fundamental questions for any economy - what to produce and in what quantities.

However, the logic is incomplete because it ignores thresholds, which are critical factors in a world of expanding populations and rising production levels. The method must therefore be modified to account for the potential destruction of human life and health caused by threshold collapses associated with production. This modification is a central element of the ecological framework.

D. THE ECOLOGICAL FRAMEWORK

1. HUMANITY AND NATURE

The relationship between humanity and nature was a highly contentious issue in the group discussion. In the view of several participants, human beings are creatures like all others, are fully integrated with and dependent on nature, and must submit to natural realities.

I agree that human beings are integrated with and dependent on nature, but in my view our species plays a unique role which must be fully acknowledged.

Human beings are part of nature in that they are biological entities, have evolved along with the planet's other life forms, and support their existence by converting low-entropy resources into high-entropy wastes.

Our species is unique in that we possess acute self-awareness, high intelligence, advanced

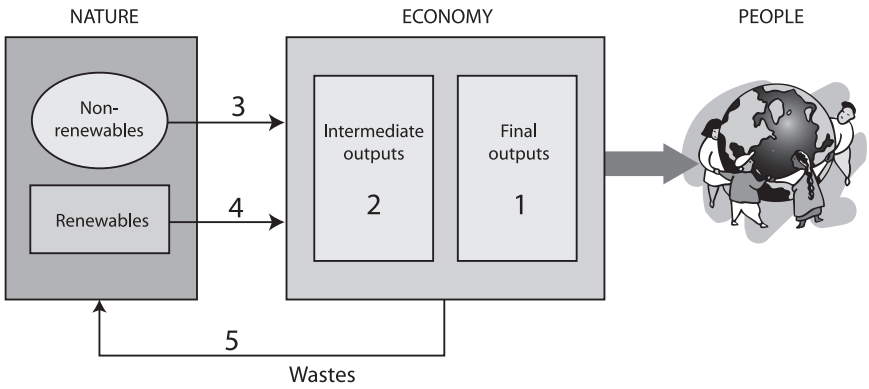

Figure 3: *The ecological abstraction*

technical capabilities, and have the resultant capacity to decisively impact the other life forms and the earth's environment. It is this potential impact that separates us ethically from the planet's non-human inhabitants.

2. THE ECOLOGICAL ABSTRACTION

To address any complex reality, a theory requires an appropriate abstraction. An abstraction is appropriate when it ignores extraneous details while highlighting the features for which the theory assumes analytical responsibility. Human economics must find an abstraction of nature that permits it to address ecological constraints in sufficient, but not excessive, detail.

Figure 3 depicts my proposed ecological abstraction:

Nature is the source of nonrenewable and renewable resources flows, and the recipient of waste flows. The economy is the consumer of resource flows, the producer of intermediate and final outputs, the source of waste flows, and the provider of outputs to human beings.

The two resource flows are separated because renewables can be exploited beyond the rate of natural regeneration, which means they are subject to thresholds. This is not true for nonrenewables, which are finite stocks that can be depleted at will. Wastes can overload natural sinks and, like renewables, are subject to thresholds.

Intermediate and final outputs are separated because they have different economic roles, and because their optimum quantities are determined in different ways.

The resource and waste flows are not further subdivided in order to restrict the scope of the ecological framework. A more detailed abstraction would encroach on the physical sciences and expand the framework beyond its analytical requirements and aims.

The numbers in the diagram indicate the five critical quantities in the nature-economy relationship. Human economics must find general conceptual approaches for determining their target values. Deriving these methods will permit us to accurately define a sustainable society.

3. ECOLOGICAL EFFICIENCY

Ecological efficiency is a relationship between a specific resource or waste flow and a final output. It is defined as the intrinsic value of the final output divided by the flow used in its production, use, and disposal. This includes the flow associated with the production, use, and disposal of all intermediate outputs in the final output's production chain.

Because final outputs usually incorporate several resource or waste flows, more than one ecological efficiency is normally associated with a final output.

Ecological efficiency is a ratio of mixed dimensions. The numerator is always in total health units, but the unit in the denominator varies with the material nature of the flow. Examples:

- Health units/board-feet of lumber (Renewable resource)
- Health units/tonne of iron (Nonrenewable resource)

- Health units/gigatonnes of greenhouse gases (Waste)

Unless ecological efficiencies are associated with the same flow, they are incommensurable and thus cannot be summed or compared.

An important objective is that human beings must strive to maximize all ecological efficiencies. This means that for any combination of final output and flow, the health gains of the output should be maximized, and the flow should be minimized.

This is an important principle because it transcends scarcity. It compels us to economize on ALL flows, not just on scarce flows. Standard economics, through prices and opportunity costs, seeks to optimally allocate only scarce inputs. It thereby neglects non-scarce resources and indirectly encourages scarcity to appear.

4. THRESHOLDS

a. Summary of the Issue

A threshold is an ecological discontinuity - the point where the flow of a renewable resource into the economy, or of a waste back to nature, triggers a sudden ecosystem collapse. In most cases, the physical sciences can determine only approximately when such a collapse will occur. Thresholds confront human economics with two distinct questions:

1. What, if any, is the ethical justification for risking a threshold collapse?
2. If such justification exists, how should the risk and consequences of collapse be analyzed?

The graph in Figure 4 will help me frame the issue:

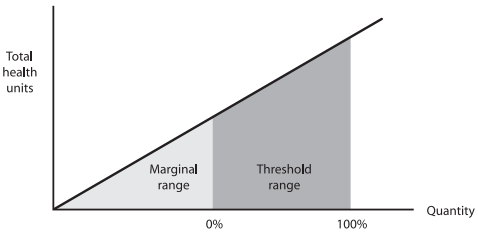

Figure 4: *Marginal and threshold ranges*

The upward-sloping line indicates that total health increases linearly with the quantity of a final output. As quantity and health increase, so does the flow of a renewable resource or waste (I assume a resource here). For simplicity, assume that only one resource flow is involved, and that it is uniquely associated with this output. The flow itself is not shown - it is expressed in terms of the output that incorporates it.

Assume that the flow's ecological efficiency has been maximized, and that no alternative output can achieve the same health effect. We therefore have an unavoidable trade-off between health and threshold risk.

From the physical sciences we learn that the flow initially poses no risk of ecological collapse. This is called the marginal range, shown in Fig 4. Within this range, the marginal analysis employed thus far is valid.

Science further informs us that this flow is subject to a threshold effect, and that a threshold range therefore exists. This is the right hand zone in Fig 4, where the probability of ecological collapse increases from 0% to 100%. Marginal analysis, which assumes continuous change, cannot be used here.

As quantity increases within the threshold range, the probability of ecological collapse tends to rise more and more rapidly. That is, the probability increase from 0% to 100% is exponential, not linear. This is not shown in the diagram, but is assumed below.

Based on the diagram, the problem can be restated as follows: should the quantity of this output enter the threshold range, and if so, how far should it rationally go?

b. Ethical Considerations

A common view among environmentalists is that human beings have no right to risk any ecological collapse, under any circumstances. While this stance appears commendable, it has extreme consequences. If strictly applied, it would prevent us from incurring even the smallest chance of collapse for an extremely localized threshold effect, while sacrificing immense potential health gains.

Imagine, for example, that farming over a large area will incur a 1% probability of driving an indigenous flower to extinction, but that the farm products will significantly improve the health of millions of poor peasants.

Does a well-founded ethical principle exist that justifies the sacrifice of such a large health

benefit to humanity for such a small risk to nature? I have been unable to formulate one, and the discussion group did not offer one in response to my request.

I tentatively conclude that - as an *economic* principle - human beings should risk threshold collapse if the potential health gains from production exceed the potential health losses from collapse.

I ignore the "inherent worth" of nature in this conclusion not because it is irrelevant, but because it falls outside the scope of economic logic. The peasant society in my example might decide to forgo the health benefits from farming in order to avoid the small risk of destroying the indigenous flower. Such a decision might be based on the inherent worth of the species, or on other ethical or cultural considerations. Any of these can legitimately override economic calculations.

c. Analytical Method

Because marginal analysis does not apply to thresholds, a different logic is required - one developed specifically to handle risk and uncertainty. Statisticians have developed several decision-making criteria to deal with such cases. Among the best-known are maximin, minimax regret, and expected monetary value.

Both maximin and minimax regret have been used to address environmental issues, but neither can incorporate the fact that the probability of threshold collapse tends to increase exponentially. Only expected monetary value permits this, making it is the most useful criterion for dealing with thresholds.

My suggested method, which is described in detail in part 4 of my paper, retains the essential aspects of expected monetary value, but transforms this into expected threshold cost. This is the probable loss of human health from threshold collapse for each level of output in the threshold zone.

As might be expected, the application of expected threshold cost to the marginal analysis can dramatically reduce the optimum output quantity. For a pervasive threshold such as that associated with global warming, the method virtually forbids entry into the threshold range. For a localized threshold with negligible health impact, on the other hand, the method permits quantity to increase beyond the threshold range, to the original optimum. This is the case in my peasant society example.

5. TARGET QUANTITIES

When I introduced the ecological abstraction I cited five sets of quantities and flows for which human economics must be find target values. These are:

1. Final output quantities
2. Intermediate output quantities
3. Nonrenewable resources flows
4. Renewable resource flows
5. Wastes flows

Final outputs are logically first because they directly support human life and health, which constitutes the economy's purpose. All the other target quantities and flows are derived from these initial targets.

To maximize human gains, the effectual value of final outputs must be maximized, and the input cost of producing these outputs must be minimized. In terms of the graph in Figure 2, this means the effectual value curve must be as close to the intrinsic value line as possible, and the input cost curve must be as low as is feasible. The optimal output quantity that results from these curves defines the maximum rational quantity for an output.

To respect ecological limits, this maximum quantity must be scaled back by the threshold logic. The optimum that results is called the **target optimum**. See Figure 5.

The target optimum is the quantity of a final output that achieves the maximum possible gains in human life and health when thresholds are taken into account. It is the starting point for deriving all the target quantities and flows. Referring to each individual quantity and flow, these are:

1. FINAL OUTPUT QUANTITY: the target optimum established above.
2. INTERMEDIATE OUTPUT QUANTITY: the minimum quantity required to produce the target optimums of all associated final outputs.
3. NONRENEWABLE RESOURCE FLOW: the quantity required to produce the optimum quantities of all associated final and intermediate outputs, at peak ecological efficiencies.

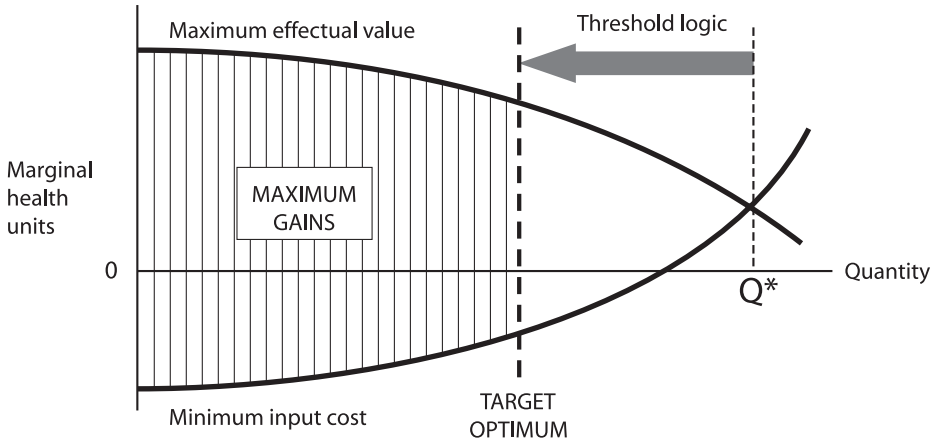

Figure 5: *The target optimum*

4. RENEWABLE RESOURCE FLOW: same as for #3. Threshold effects have already been considered in establishing the optimum quantities for the associated final outputs.
5. WASTE FLOW: also the same as for #3. Again, threshold effects have already been considered.

To summarize, the target quantity of a final output is derived by maximizing its associated health gains and applying threshold logic. We then work backwards through the production chain to find the target quantities of its associated intermediate outputs and flows.

Applied to the economy as a whole, this logic maximizes human well-being while respecting ecological constraints. In other words, it achieves the objective of human economics.

E. A HUMANE AND SUSTAINABLE ECONOMY

I am now in a position to define sustainability. For clarity, I limit the scope of the term to an economy's ecological soundness. If an economy adequately meets human needs it is referred to as "humane".

I reject two common notions:

1. Sustainability is not the same as stability, or lack of change. An economy can be extraordinarily dynamic and still be ecologically sound.
2. Sustainability does not mean living off self-regenerating renewables. Nonrenewable resources can sharply increase human well-being. To leave such resources untapped is not a triumph of environmental integrity, but a collapse of human reason.

In my view, sustainability refers to the maximum justifiable rates at which an economy can consume the earth's resources. As an ethical principle, I suggest that there is no better use for any resource or waste flow than meeting the vital needs of the present generation. Since future generations issue from our bodies, our health is the basis for their health. Fully meeting our vital needs is thus more than justified, it is a moral imperative.

Using the concepts introduced above, an economy is sustainable if its resource and waste flows do not exceed their target quantities. It is humane to the extent that each of its final outputs approaches its target optimum.

If all five target quantities are achieved, the result is a humane and sustainable economy.