WASTING ‘EFFICIENCY’: SISYPHUS AND THE POLICY MAKER

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ABSTRACT

Efficiency forms the bedrock of policy, planning and business approaches to sustainable development, but ‘efficiency’ has many meanings. Efficiency, in the resource-use context, has a wide range of potential interpretations from the ratio of work output to energy inputs, to Pareto efficiency. Despite the potential richness of the efficiency concept, in practice, efficiency is often narrowly conceived within disciplinary boundaries. This appears to be the case even in ecological economics which aims to be 'transdisciplinary' and pluralistic. Such narrow disciplinary perspectives essentially waste the richness of the efficiency concept. This wasting of efficiency concepts could mean decision makers are destined to Sisyphean toil in the pursuit of sustainable development.

This paper explores the efficiency concept and its interpretation. The discussion presents a three-tiered nested hierarchy framework within which a truly ecological economic approach to efficiency can emerge. Within this framework, it is argued that efficiency must be subordinate to both decisions about scale and other social decisions. Armed with this framework, policy makers and planners will be better placed to make decisions leading to sustainable businesses and society.

Keywords: efficiency; policy analysis and planning; ecological economics; ecology; thermodynamics

INTRODUCTION

Decision criteria play an important role in the policy and planning process (Patton & Sawicki 1993; Quade 1982). One criterion that has tended to dominate contemporary policy development and evaluation is efficiency – leading to what Stein (2001) refers to as the ‘cult of efficiency’. As Epstein (1984 p. 10) states, “everyone wants government policy to be more efficient”.

Examples of this ‘efficiency cult’ abound. As a result of the continued call for the use of efficiency analysis in policy and planning, many texts have been written on the subject, including Williams and Anderson (1975), Epstein (1984), Leach and Stewart (1982) and Nagel (2001). Epstein (1984), in particular, advocates efficiency measures as an essential tool for policy evaluation because “efficiency measurement can provide both external accountability and the internal accountability for local government performance” (Epstein 1984 p.10). Even the political scientist Wildavsky (1966 p. 309-10), in his early critique of efficiency in policy analysis, acknowledges that “studies based on efficiency criteria are much-needed and increasingly useful”.

‘Efficiency’ also plays an important role in many national policy contexts. For example, the concept of efficiency is enshrined in several of New Zealand’s core statutes, including the State Sector Act (1988), Resource Management Act (1991), the Energy Efficiency and Conservation Act (2000) and the Local Government Act (2002). Furthermore, efficiency is a core criterion for many of New Zealand’s resource allocation activities (see, for example, Transit New Zealand’s Project Evaluation Manual). Finally, many government documents advocate the use of the efficiency criterion (for example, see Caragata 1989).

The efficiency criterion is a potentially rich concept: it has a wide range of interpretations, from the ratio of work output to energy inputs, to Pareto efficiency. However, in contemporary efficiency practice, the concept is often conceived within narrow disciplinary boundaries. Such narrow perspectives essentially waste the richness of this concept. This wastage can limit decision makers' ability to make ecologically sustainable decisions and destine decision-makers to Sisyphean[1] toil in the pursuit of an ecologically sustainable society.

This paper explores the efficiency concept and its interpretations. This paper first discusses the meaning and etymological origins of "efficiency". It then explores several different disciplinary perspectives on the efficiency concept. Finally, it presents a framework within which a multi-dimensional approach to efficiency can emerge. Armed with this framework, policy makers and planners will hopefully be less likely to follow Sisyphus on his uphill journey and instead will be better placed to make decisions leading to ecologically sustainable businesses and society.

THE ORIGINS AND MEANING OF EFFICIENCY

The English word 'efficiency' is derived from the Latin word *efficientia*, the present participle of the verb *efficere. Efficere* means to bring about, accomplish, execute or produce (Skeat 1961) . The infinitive is itself derived from a combination of *ex-* (after) with the Latin verb *facere,* to do or make (Barnhart 1988).

The interpretation of efficiency evolved in two directions, both of which derive from theology. In one direction, efficiency evolved to refer to the action of an 'operative agent' – God. This use of the term is now generally obsolete.

In the other direction, efficiency came to be used to mean 'fitness or power to accomplish, or success in accomplishing, the purpose intended' (Simpson & Weiner 1989 p. 84). The 'fitness or power to accomplish' interpretation of efficiency was taken from theological themes and, in the context of the rationalist spirit of the Enlightenment and the commercial activity of 18th century Europe, was applied more widely to the transient world. In doing so, the core meaning of efficiency interpretations shifted from a theological, spiritual basis to a Western-scientific, 'logical-positivist' realm.

Two threads are evident within this new approach to efficiency. First, efficiency is applied to the 'productive machine'. In 1827 Gilbert used the word efficiency in relation to physics: the work done by a force in operating a machine or engine (Simpson & Weiner 1989) . He stated, "therefore a machine is efficient in producing duty, or effect, in proportion to the force applied, multiplied into the space through which it acts, I propose to denominate this function ($f \times s$) *efficiency"*. Similarly, 'efficiency' was used in relation to the 'organic machine' in biological literature as early as 1925 (Lotka 1925).

A second thread in contemporary efficiency is to do with the economics of resources and welfare. Efficiency began to enter the economic lexicon in the 1800s. Fawcett (cited in Simpson & Weiner 1989) stated in 1863 that "nothing more powerfully promotes the efficiency of labour than an abundance of fertile land". The most widely used contemporary interpretation of economic efficiency is related to the work of Vilfredo Pareto. His work led to what is now referred to as allocative efficiency or simply Pareto efficiency. (Resources are allocated in a Pareto-efficient manner when it is not possible to change the allocation of resources without making someone worse off.)

Since the 1800s and the wider application of the efficiency term, the number of efficiency concepts has burgeoned. Efficiency concepts now include technical efficiency, production efficiency, profit efficiency, x-efficiency, allocative efficiency, scale efficiency, thermal efficiency and finite-time efficiency, managerial efficiency, dynamic efficiency, ecological efficiency and many more.

The term 'efficiency' is now tied to the rationality of a logical-positivist world view. In fact rationality and efficiency are often used synonymously, as Daly (1992a, p. 192) shows: "this argument is raised against economists who [argue that] ... intertemporal allocation via discounting the future is the *rational (efficient)* way to deal with provision for the future" (emphasis added). However, the concept of efficiency has still retained a notional link to spiritual zeal. In Western cultures, efficiency, along with concepts such as

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[1] In Greek mythology, Sisyphus was a cruel King of Corinth condemned forever to roll a huge stone up a hill in Hades only to have it roll down again on nearing the top. The gods thought with some reason that there is no more dreadful punishment than futile and hopeless labour.

‘productivity’, ‘usefulness’ and ‘thrift’, embodies the Christian dogma of transcendence over nature (White 1967).

In sum, the modern interpretation of efficiency can be traced to both spiritual and scientific roots. It is a powerful concept that embodies the notion of ‘fitness or power to accomplish, or success in accomplishing, the purpose intended’. However, Stein (2001) stresses that the modern efficiency concept is context-dependent. Efficiency embodies two aspects: ‘fitness or success’ and ‘the purpose intended’, both of which depend on the context. For example, it is important to ask ‘what is the purpose intended’? Is the purpose to improve the productivity of a machine, or enhance the welfare of our community, or something else? The yardstick of efficiency “is relative and rooted in context” (Stein 2001 p. 12).

EFFICIENCY IN DISCIPLINARY CONTEXTS

The term ‘efficiency’ has come to have a multiplicity of meanings. Any single interpretation of efficiency is contextually bound to a particular set of disciplinary and epistemological assumptions. This section explores the insights into efficiency that have emerged from three disciplines that have developed efficiency concepts as part of their core scientific enquiry: thermodynamics, economics and ecology.

Thermodynamic approaches to efficiency

Efficiency has been a core focus of classical thermodynamics[2] since the beginning of the science. This core importance has arisen primarily because of classical thermodynamics’ conception during the industrial revolution and its preoccupation with increasing the efficiency of industrial-revolution machines (Khalil 1990; Kondepudi & Prigogine 1998 ; O'Connor 1994). The concept of thermodynamic efficiency was first developed in connection with steam engines: an engine was more efficient if it could, for example, pump more water while using the same quantity of coal (Ayres & Nair 1984).

The work of early thermodynamicists has led to an empirically precise definition of efficiency that is based on measures of physical, often observable, systems. Efficiency concepts within thermodynamics are all based on the same formulation:

$$Efficiency\ (\eta) = \frac{useful\ output}{input} \qquad \textbf{Equation 1}$$

Thermodynamic concepts of efficiency have several dimensions and can be divided into four groups: thermal efficiency, efficiency based on ideal limits, finite-time efficiency and energy-quality adjusted efficiency measures.

As with any disciplinary perspective, care must be taken when using these concepts. Classical thermodynamic interpretations of efficiency are a product of the discipline’s assumptions and the way it views reality. In particular, thermodynamic concepts could be criticised for being too preoccupied with machines of work (O’Connor 1994), with assuming that systems deterministically tend toward equilibrium (Khalil 1990) and for being based on the notion of an ideal ‘reversible’[3] system (Ruth 1993).

These preoccupations have implications for the way classical thermodynamics formulates efficiency concepts. The preoccupation with controllable machines of work could imply that efficiency is likewise controllable. In complex systems with non-linear feedback, this may not be the case. Also, in an ‘equilibrial world’, efficiency is assumed to converge on a unique final value through the relentless march towards equilibrium. Since non-equilibrium systems are ubiquitous in nature, a classical thermodynamic equilibrium-based approach to concepts such as efficiency must be treated with caution.

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[2] The following focuses on efficiency concepts in classical (or macroscopic) thermodynamics rather than statistical thermodynamics. This is because most of the work on efficiency concepts has emerged from classical thermodynamics.

[3] A process is called reversible if, after its conclusion, the system may be restored to its initial state.

Neoclassical economic approaches to efficiency

Since its inception, economics has focused on natural-resource scarcity (Randall 1987 , p. 3). This focus naturally leads to a concern for the efficiency of resource use. As early as the Physiocrats (1750-1780), notions of the environment, resource use and efficiency were alluded to. The classical school of economics (1775-1875) pointed out that all resources (capital, labour, land) contribute to wealth. Many classical economists, for example Ricardo and Malthus, also emphasised the importance of natural resource constraints. However, after Adam Smith's treatise that outlined (among other things) a system for efficiently allocating resources, emphasis on the importance of natural resource constraints waned. Neoclassical economists have continued this trend, tending to focus efficiency concepts on the human-welfare implications of resource allocations rather than the need to prevent resource extinction.

Efficiency remains a core concept of neoclassical economics (Leibenstein 1966). In fact, "many mainstream economists regard the domain of economics to be limited to matters of efficiency" (Woodward & Bishop 1995 p. 104) .

In economics, efficiency is not a single notion, but rather is 'a multidimensional concept' (Helm 1988 p. 13). These many facets of efficiency can be found in two main bodies of theory: production theory (such as technical efficiency, production efficiency etc.) and welfare economics (such as allocative efficiency, intertemporal efficiency etc.).

A neoclassical economic approach to efficiency is influenced by a number of underlying assumptions about economic activity. In particular, neoclassical economics, and by implication its concept of efficiency, has been criticised because of its mechanistic, deterministic and atomistic view of the economic system (Söllner 1997). The implication of this world view is that neoclassical economics assumes that given the right conditions, the market machine will inevitably and instantly achieve equilibrium levels of efficiency in its many guises. It is hard to find a justification for this view. There is little empirical evidence that economic systems tend deterministically towards equilibrium. Instead, we see an economy characterised by "non-equilibrium (and) self-reinforcing behaviour" (Christensen 1991 p.75).

Neoclassical economics also tends to implicitly view the economy as a closed system. As Sir John Hicks states, "it is because the range of phenomena with which economists deal is so narrow that economists are so continually butting their head against its boundaries" (quoted in Norgaard 1985 p.388). Viewing the economy as a closed system has two implications for efficiency. First, a neoclassical approach to efficiency tends to be restricted to the immediate, direct effects of an action within the closed system; wider flow-on effects are ignored. Second, closed-system assumptions lead to resource misallocations. The only way to avoid resource misallocations is to recognise that the economy is an open system from both economic and thermodynamic perspectives (Amir 1994 p.140).

Ecosystem ecology approaches to efficiency

Ecology adds yet more efficiency concepts. As prominent ecologist Howard Odum (1971 p. 92) states, "many names have been used to describe various kinds of efficiency, and definitions are not always clear".

Concern for efficiency in ecosystem ecology theory has a shorter history than in thermodynamics or economics. According to Martinez-Alier (1987 p. 9) it wasn't until the mid-19th century that ecologists came to consider the efficiency and transformation of energy by plants and animals as a central question in their research. Lotka (1925) was among the first to apply the idea of efficiency directly to biological systems. Following thermodynamics, he defined efficiency as the fraction of energy (Q) converted into work (W). By the 1940s, various efficiency ratios were being calculated by ecologists. But perhaps the most important contribution to the concept of ecological efficiency came from Raymond Lindeman (1941; 1942).

Lindeman was the "first to implement Tansely's ecosystem concept in a quantitative effort to define the system and describe and understand its dynamic behaviour" (Golley 1993 p. 50) . Lindeman's coupling of thermodynamics and ecology was a watershed for ecosystem ecology's notion of efficiency. In particular, it enabled ecologists to quantify the energy and material flows through trophic levels and therefore to develop mathematical models.

By applying energetic analysis, Lindeman defined ecological efficiency as:

$$\textit{Efficiency } (\eta) = \frac{\textit{secondary consumers (or producers)}}{\textit{primary consumers (or producers)}} \qquad \textbf{Equation 2}$$

Discussion of efficiency concepts in ecological literature can be grouped into three areas: Eugene Odum's (1983) 'efficiency between and within trophic levels', Howard Odum's transformity (Odum 1971 1996) and the maximum power principle (Odum & Pinkerton 1955).

An ecosystem ecology perspective provides several insights into efficiency. In particular, this perspective:

- promotes a mix of holistic and reductionistic analyses of efficiency (Koestler 1978);
- emphasises the importance of boundaries in an analysis of efficiency (Golley 1993; Odum 1996; O'Neill 1986);
- acknowledges complexity and questions an equilibrial view of systems (Golley 1993; Hagen 1992; Odum 1983).

An ecological approach to efficiency is firmly rooted in what Wiegert (1988) refers to as ecological energetics: a focus on energy flows through the ecosystem. This approach is limited in several ways. It ignores some complex inter-relationships (such as interspecies relationships); it emphasises the quantitative rather than the qualitative (and is therefore prone to the '*pars pro toto*' trap where the part is seen as the whole); and the commonly accepted 'objective' view of efficiency implied in energetics is misleading (the efficiency concept is inherently subjective). The mere focus on efficiency in ecological research reveals a value judgement about the importance of efficiency.

Summary of disciplinary approaches to efficiency

The three disciplines just discussed provide a rich mix of efficiency concepts, many of which can be used to guide policy. For example, New Zealand's Energy Efficiency and Conservation Authority's Minimum Energy Performance Standards policy focuses on the thermal efficiency of appliances. Ecology's maximum power principle could be used to guide policy by helping to quantify the trade-off between speed of operation and efficiency. However, as I will demonstrate below, the efficiency criterion is dominated by allocative efficiency applications.

Another emerging field of enquiry relevant to a discussion of efficiency is ecological economics, which claims to take a 'transdisciplinary', pluralistic' approach to sustainable development (Costanza *et al.* 1991; Norgaard 1989; Sahu & Nayak 1994). Because of this pluralistic approach, one would expect less dominance of allocative efficiency applications. However, on closer examination, the work of many ecological economists still reflects the current policy preoccupation with allocative efficiency.

ECOLOGICAL ECONOMIC APPROACHES TO EFFICIENCY

The concept of efficiency has had a long history in ecological economic tradition (consider the Physiocrats and early classical economists such as Ricardo and Malthus), and efficiency continues to play a vital role in contemporary ecological economic theory. The basic world view of ecological economics is that the world economy's energy and material resource base is limited (Costanza *et al.* 1991). A direct conclusion arising from this biophysical perspective is that energy and material resources must be used efficiently. Ecological economics identifies efficiency of resource use as an important strategy for achieving sustainable development (Ayres & Nair 1984; Templet 2001).

However, ecological economic literature clearly does not regard efficiency alone as being sufficient for sustainable development, for two related reasons: efficiency is subject to 'thermodynamic limits,' and efficiency faces 'social limits.' Efficiency is wholly inadequate to address issues of scale and distribution, which depend on ecological realities and social, political and ethical principles respectively. Ecological economic literature is also clear that efficiency should not be considered in isolation (Daly 1992a; Norgaard & Howarth 1992). Daly (1996 p. 219) argues that efficiency (coupled with sufficiency, equity and sustainability) needs to become part of a new 'central organising principle' to replace 'growth mania'. Ecological economic theory saves an important place at the sustainable development table for efficiency-enhancing strategies. However, efficiency in itself is not regarded as sufficient for achieving sustainability goals.

The concept of efficiency in ecological economics

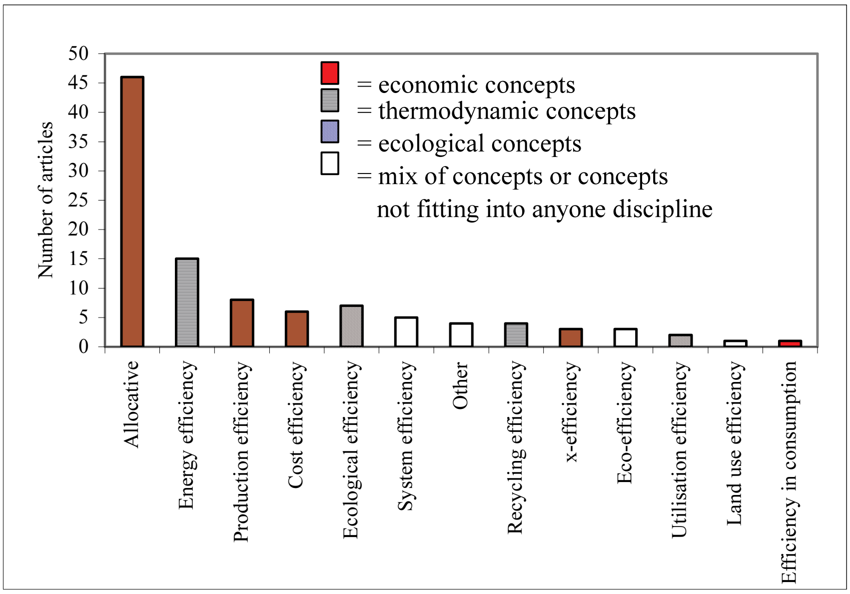
Despite efficiency having an important place in ecological economic theory, little work has been done to develop an ecological economic approach to efficiency. The rhetoric of ecological economics suggests that a theory of efficiency should:

- focus on integrating ecological and economic theory;
- be based on a biophysical perspective of economic-environment interactions;
- take a systems perspective;
- link efficiency concepts with sustainable development;
- be inter/transdisciplinary.

Current usage of the efficiency concept in ecological economics – literature review

Regardless of the rhetoric of ecological economics, "ecological economics will, in the end, be what ecological economists do" (Costanza 1989 p. 2). A review of 91 articles in the journal *Ecological Economics* (volumes 1 through 42) that discuss efficiency[4] provides useful insights in this regard. The analysis of these papers indicates that there is a divergence between ecological economic theory and revealed practice.

Taken together, the 91 papers covered an appropriately diverse range of efficiency concepts, from allocative and x-efficiency to ecological and food-conversion efficiency. This aggregate view is misleading, however. The review found that the ecological economic literature is dominated by applications of economic efficiency concepts (70 percent of the 91 articles reviewed), and by allocative efficiency in particular (51 percent of all 91 articles) (Figure 1). In fact, 33 of all of the articles applied the allocative efficiency concept in isolation of other efficiency concepts or wider social, ecological or thermodynamic considerations. These articles present research that is essentially indistinguishable from neoclassical economic analyses.



[4] That is, those articles that mention efficiency in the keywords or abstract.

Figure 1: Number of efficiency-related articles in the journal *Ecological Economics* (volumes 1 through 42) by type of efficiency concept[5] and discipline[6]

Thermodynamic-related efficiency concepts (energy efficiency and recycling efficiency categories in Figure 1) were applied in approximately 20 percent of the articles. Most of these articles addressed issues of energy efficiency from a thermal-efficiency perspective, and only three articles actually attempted to draw energy quality considerations into the ecological economic literature (Amir 1994; Azar *et al.* 1996; Matutinovic 2002).

Few articles (10 percent) drew on ecological theory of efficiency. This is surprising, given ecological economics' supposed attempt to integrate ecological and economic theory.

Another interesting finding is that, despite ecological economics' call for pluralism, only 11 articles attempted to use more than one efficiency concept in their analysis. Of these articles, five used only economic concepts (Aldy *et al.* 1998; Felder & Schleiniger 2002; Khanna & Zilberman 1997; Regev *et al.* 1998; Ricker 1997). The remaining six papers drew on efficiency concepts from more than one discipline and could be regarded as 'interdisciplinary.'

Another finding from the review is that many of the authors did not try to define efficiency. Only 31 percent of the papers offered a definition of the efficiency concept they used. The rest simply assumed that the reader would understand the specific efficiency concept under consideration. This absence of efficiency definitions is of concern because the range of efficiency concepts available to ecological economists is potentially far greater than in mono-disciplinary research. Without explicit definitions there is considerable room for confusion over what concept is actually represented by the word 'efficiency'.

In conclusion, it appears from this review that what ecological economists 'do' with respect to efficiency leaves much to be desired. One potential remedy to this situation might be the development of a framework for ecological economic efficiency analyses. This framework would be based on ecological economic theory and would be designed to encourage an interdisciplinary and pluralistic approach to efficiency. It would also allow policy analysts to locate their specific efficiency analysis within the broader policy context.

TOWARDS AN ECOLOGICAL ECONOMICS FRAMEWORK FOR EFFICIENCY

Despite the richness of approaches to efficiency derived from the different theoretical bases, to date there has been no attempt to reconcile these in ecological economics literature. Currently, no conceptual framework exists that can accommodate this multi-dimensionality without losing either the core meaning of the term or the richness of the approaches. This lack is a significant obstacle to our ability to fully use the efficiency concept. The ecological economic framework presented in Figure 2 draws on ecological economic theory and attempts to address this shortcoming. The framework is normative and consists of a nested hierarchy of three tiers: scale considerations, goal setting and efficiency.

The implications of this framework are important. The framework does not aim to show where economists' interpretations of efficiency are right and ecologists' and thermodynamicists' interpretations are wrong, or vice versa. Each discipline takes the core meaning of efficiency, surrounds it with different assumptions, and applies it to different areas of interest. Instead of seeing this as a problem, this framework views diversity as an asset.

A nested hierarchy three-tiered framework

It is important to decide where in the framework to place efficiency. Although necessary, efficiency alone is will not guarantee an ecologically sustainable future (Templet 2001). In other words, progress towards an

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[5] The 'other' category contains 'overall efficiency', 'absolute efficiency of cars and buses', 'efficiency of monitoring systems' and 'efficient attribute combination.'

[6] Note that the number of efficiency concepts presented in this figure add to more than the number of articles, because several articles mention more than one efficiency concept.

ecologically sustainable society will certainly require an improvement in the efficiency of resource use, to help delay resource exhaustion, but just improving efficiency will not achieve the sustainable nirvana. This is because efficiency improvements will not prevent the depletion of non-renewable resources. The best that efficiency can do is slow the rate of resource depletion. Other action is needed beyond improvements to resource use.

The ability of efficiency to contribute to an ecologically sustainable economy is limited. Therefore efficiency must be made subordinate to broader considerations. In particular, it is suggested that the goals of sustainable physical scale[7] (Daly 1992b),and social goals such as equitable distribution (Daly 1992b; Norgaard & Howarth 1992), need to be considered before efficiency goals are pursued. Therefore, they form tiers 1 and 2 of the framework.

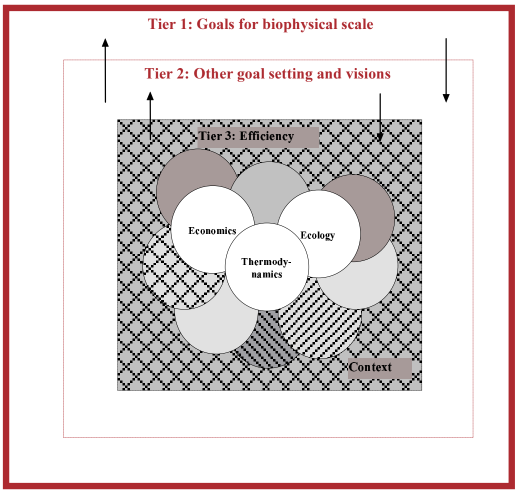

Figure 2: A proposed ecological economic framework for efficiency.

Two slightly different approaches to dealing with the scale, social goal setting and efficiency tradeoffs are found in ecological economics literature (see Daly 1992b and Norton *et al.* 1998). In order to develop a workable framework in which to locate efficiency, it is useful to combine the insights from both of these approaches. Consistent with Daly's model, the first or primary tier of the framework (Figure 2) necessarily requires consideration of biophysical scale. This tier is superior to, but interacts with, other goal setting that considers social issues (such as equity and visions of the future).

In ecological economics the issue of scale is fundamentally different to other issues considered in tier 2. While decisions about scale are decided by social processes, they must reflect physical limits (Daly 1992b). Scale effects are inescapable (Costanza *et al.* 1991; Daly 1996; Hardin 1991). Daly illustrates the fundamental nature of scale effects with a nautical plimsoll line analogy. The plimsoll line indicates how well weight has been arranged on board to keep the ship level. Even if a boat is loaded so it keeps perfectly level, it still sinks if it is simply loaded with too much cargo. Similarly, the economy may be succeeding with respect to social goals, but it can still 'sink' because it has exhausted the limited physical resources from the environment on which it depends. Other issues such as the type of governmental structure, or the mode of health-care provision within the first tier of Norton *et al*.'s (1998) model, are less dependent on ecological limits. This leads to Costanza's (1989 p. 5) comment that "issues of sustainability are ultimately issues about scale".

Following Norton *et al.* (1998), the second tier involves reflective social goal setting. This tier is regarded as being subordinate to the scale tier, but superior to the third tier – efficiency. Furthermore, the framework acknowledges the need for interaction and movement between tiers (shown in Figure 2 as arrows between tiers).

[7] 'Scale' is essentially shorthand for the physical scale or size of the human presence in the ecosystem.

Describing the third tier: the efficiency space

Decision criteria in general are located within the third tier of the framework. In this paper, the focus of the third tier is on efficiency as a decision criterion. In the context of efficiency this third tier can be understood by describing the role of efficiency as a decision tool, the context-dependent nature of efficiency and the plurality that must be embodied in any consideration of efficiency.

As a third tier concept, efficiency is used to aid decisions on how to "best" pursue the goals set in tiers 1 and 2. Whether the decision is related to a simple machine, or a more complex system, understanding efficiency can help decision-makers to identify where changes to the system of interest should occur, if at all. However, efficiency cannot be used as a decision criterion in isolation, nor will it be appropriate to use the efficiency criterion in all circumstances. In the context of constant interactions between tiers, locating efficiency within the third tier is useful because that highlights the limit of efficiency as a decision tool, as well as the tradeoffs, the necessary hierarchy and the complexity of decision-making involving economy-environment interactions.

Efficiency concepts are context dependent (Stein, 2001). That is, the meaning of 'efficiency' is dependent not only on the goals set in tiers 1 and 2 as discussed above, but also on the disciplinary perspective and the nature of the system under consideration. The efficiency concept that is chosen to assist decision-making in tier 3 is also dependent on the analytical purpose. For example, consider a broad social policy goal (as set in tier 2) of greater responsibility in the use of non-renewable resources. If the focus is on meeting this goal in the electricity generation sector, then an understanding of the thermal efficiency of generation plants may suffice. If, however, the focus is on the use of resources within a factory, the production efficiency concept would be more helpful in aiding decisions.

Because of the context-dependent nature of efficiency, tier 3 should not be tied to one efficiency concept (as shown by the different, interrelated spheres embedded in the third tier). Rather, it should be described as interdisciplinary and pluralistic. This interdisciplinary and pluralistic description is appropriate given that the contexts within which efficiency can be applied can vary so dramatically. It is also appropriate given ecological economics' pursuit of pluralism. Thus, rather than defining a single efficiency concept, tier 3 can be considered a multi-dimensional space that accommodates a pantheon of interrelated perspectives of efficiency. In this way, tier 3 manifests a core conclusion of this paper: that a combined application of the efficiency concepts from thermodynamic, economic and ecology disciplines can describe efficiency more richly than is possible with methods borrowed from a single discipline. This perspective is motivated by ecological economics' attempts to release decision makers from Sisyphean toil as well as the pursuit of new insights into the relationship between economic processes and environmental repercussions.

In sum, a multi-dimensional, interdisciplinary third tier helps to encourage ecological economics to move towards Norgaard's (1989) 'methodological pluralism', and a more pluralistic appreciation of the efficiency concept.

Conclusion

Contemporary policy and planning approaches to sustainable development rely heavily on the efficiency criterion. However, efficiency has a wide range of potential interpretations deriving from thermodynamic, economic and ecological theory. Unfortunately, despite the potential richness of the efficiency concept, in practice, efficiency is often narrowly conceived within disciplinary boundaries. This appears to be the case even in ecological economics, which aims to be 'transdisciplinary' and pluralistic. Such narrow disciplinary perspectives waste the richness of the efficiency concept.

This paper has explored the efficiency concept and its interpretation, and has presented a framework within which a truly ecological economic approach to efficiency can emerge. Armed with this framework, policy makers and planners will be less likely to suffer from the curse of Sisyphus and be destined to continually push their burdens uphill only to have it roll down hill again before the goal is reached. Instead, this framework will hopefully help policy makers to use efficiency concepts to achieve their goals of ecologically sustainable businesses and society that lie at the top of the proverbial hill.

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