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Editorial
Beyond Eco-Efficiency: a Resilience Perspective

Jouni Korhonen[1]* and Thomas P. Seager[2]
[1] *Âbo Akademi University, Turku, Finland*
[2] *Golisano Institute for Sustainability, Rochester Institute of Technology, Rochester, NY, USA*

ABSTRACT
Business strategy with regard to sustainability is currently dominated by an eco-efficiency approach that seeks to simultaneously reduce costs and environmental impacts using tactics such as waste minimization or reuse, pollution prevention or technological improvement. However, in practice, eco-efficiency optimization rarely results in improved diversity or adaptability and consequently may have perverse consequences to sustainability by eroding the *resilience* of production systems. This editorial article contrasts a resilience approach with an eco-efficiency approach as they relate to strategic sustainable development. In some cases, the system attributes that are critically important to resilience – such as spare capacity, reserve resource stocks and redundancy – are in opposition to eco-efficiency. Our most important insight is the realization that investments in what may seem counter to eco-efficiency can nonetheless be important for sustainability. Copyright © 2008 John Wiley & Sons, Ltd and ERP Environment.

Keywords: eco-efficiency; strategic sustainable development; resilience

Introduction

AS MANUFACTURING AND BUSINESS OPERATIONS HAVE SOUGHT TO INCORPORATE PRINCIPLES OF SUSTAINABILITY INTO measurable operational objectives, they have increasingly adopted a perspective that can be characterized as *eco-efficiency* (EE). The concept is defined as increasing productive output while using fewer resources (Schmidheiny, 1992; Welford, 1998) or units of value generation per unit of environmental influence (Brattebo, 2005; Huppes and Ishikawa, 2005). Strategies for achieving eco-efficiency include lean manufacturing, waste minimization or beneficial reuse, investing in technology improvements that raise material or energy yields, and shifting energy resource demands from petroleum based to renewable (such as wind or solar power). The result is almost universally accepted as beneficial to both the economy and the environment (Porter and van der Linde, 1996), as well as supportive of sustainability from the standpoint of meeting current needs while conserving resources for the benefit of future generations. The concept of eco-efficiency has been increasingly cited in public policy (see, e.g., Hukkinen, 2003a, 2003b), cleaner production (Stevenson and Evans, 2004), industrial ecology (Ehrenfeld 2005) and corporate environmental and sustainability management (Figge and Hahn, 2004). The European Union (EU), Organization of Economic Cooperation and Development (OECD) and World Business

* Correspondence to: Dr. Jouni Korhonen, Akademi University, Turku, Finland, Biskopsgatan 8, FI-20500, Åbo, Finland. E-mail: jouni.korhonen@abo.fi

Council for Sustainable Development (WBCSD) promote EE as the universal concept in sustainable development, environmental policy and corporate environmental management (see, e.g., WBCSD, 2000; OECD, 1998).

Efficiency, as a normative ideal, has always been a central concept in neoclassical economics that has strongly influenced many other scientific fields, including fields originally deemed outside the realm of economics (e.g., Lazear, 2000). The advantage of an EE approach from a strategic business perspective is that it lends itself to measurable objectives that are consistent with a continuous improvement or quality-focused management culture. EE is well suited to the existing theories of business economics. For example, a *carbon footprint* is a measure of the land area that would hypothetically be required to sequester the carbon dioxide released to the atmosphere over the life cycle of a product or service (see, e.g., Wackernagel, 2008). As the concept of the metaphorical footprint has gained popularity, so have management efforts to track carbon emissions as a function of design, production, use and final disposition of manufactured products. The implication is that the footprint should be trending downwards. Similarly, the publication of the Toxic Release Inventory in the United States has drawn attention to manufacturing facilities that are perceived as poor neighbours or bad actors. As the information on toxic releases has become more available, so has public and management pressure to reduce emissions – even as production runs increase (see, e.g., Seager *et al.*, 2007). The aggregate effect is presumably a higher quality of life.

Despite all the benefits of EE, it is now well recognized that economic efficiency improvements can result in price reductions that encourage increased consumption. In the context of environmental sustainability, the phenomenon of improved efficiency on an intensive (or per product) basis creating new demands for products that adversely impact the environment on an extensive basis (total product consumption) has been termed the *rebound effect* (see, e.g., Hertwich, 2005; Binswager, 2001; Berkhout *et al.*, 2000). Ironically, resource scarcity can result even as efficiency improves – a phenomenon now known as *Jevon's paradox* and well documented in the literature (e.g. Alcott, 2005).

In this editorial, we raise other concerns with regard to eco-efficiency that, from a broader systems perspective, may have counter-intuitive consequences with respect to sustainability. *In particular, loss of spare capacity, diversity or flexibility may degrade the resilience of ecological or industrial systems, thereby undermining long term sustainability even as measures of eco-efficiency improve.* For example, application of pesticides (in agriculture) or use of antibiotics (in animal husbandry) that resulted in immediate productivity and efficiency gains also resulted, in the longer term, in pesticide and antibiotic resistance that ultimately increased expenses and destabilized production systems (see, e.g., Orzech and Nichter, 2008). We argue that analogous conditions exist in business. It may be beneficial to adopt practices that may be inefficient in terms of eco-efficiency, but supportive of a systems-wide, long term view of sustainability.

On Resilience and Sustainability

Resilience

The concept of resilience was first developed in ecology to describe the capacity of a natural system to recover from perturbation or injury. Compared with EE, which lends itself to development of operational management metrics, the concept of resilience is less precise. The specific attributes of resilient systems are context dependent and there is no single consensus view of resilience that informs all systems. In particular, there is a contrast between interpretations of resilience in technological and ecological systems (Holling, 1996).

In engineering, Fiksel (2003) lists diversity, efficiency, adaptability and cohesion as characteristic of resilience. 'Diversity' implies a wide range of alternatives, such as multiple product offerings or production sites. 'Efficiency' refers to resource productivity, including eco-efficiency. 'Adaptability' describes the ability of an organization to change practices, resource allocations, designs, relationships or other aspects of the business in response to changing conditions. 'Cohesion' is taken to mean the strength of relationships internal and external to the organization such as customer loyalty, supplier relationships, corporate culture and employee identity.

Walker *et al.* (2004) construct a different understanding of resilience applicable more directly to natural systems. They describe the critical aspects of resilience as latitude, resistance, precariousness and panarchy. 'Latitude' refers

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to the elastic range in which a system can be perturbed or deformed without losing the ability to return to its original form. 'Resistance' is the difficulty or force required to create a unit change in the system – such as stiffness in material engineering. 'Precariousness' describes how close the system is to exceeding the elastic threshold and undergoing a permanent restructuring. Last, 'panarchy' refers to cross-scale interactions and how perturbations at one scale may create regime shifts at some other scale of observation.

Whereas Fiksel (2003) lists adaptability as part of resilience itself, Walker *et al*. (2004) draw a distinction between resilience, adaptability and transformability. In this case, if resilience is characterized by the four attributes of latitude, resistance, precariousness and panarchy, then 'adaptability' refers to the ability of human actors within the system to manipulate these characteristics, for example, increasing the operational latitude or armouring the system so that it requires greater force or disturbance to effect an equivalent change. Strategies for adaptability in human systems may very well involve technology or reengineering, but on an adaptability trajectory the basic system state remains recognizable as having all the elements of the original state. Consequently, the two descriptions of adaptability may be interpreted as consistent with one another.

However, transformability describes a change into a very different state, from which the original state is unlikely to be accessible (i.e., the change is irrevocable). This concept is entirely absent from the Fiksel (2003) description, as well as other descriptions pertaining to industrial systems (e.g. Handmer and Dovers, 1996). Interestingly, it remains a topic of debate whether the change required in business to achieve sustainability can be incremental, as suggested by the adaptability trajectory, or necessitates a radical paradigm shift, as suggested by a transformability pathway (Ayres, 2008; Ehrenfeld, 2000; Welford, 1998).

Risk Versus Resilience Perspectives

Business strategists are generally familiar with the concept of risk, but in the case of sustainability, risk may manifest in several dimensions: financial (such as the risk of counter-party default on contracts), environmental (such as worker and consumer safety from toxins) and socio-political (such as regulatory or market preference risks). Nevertheless, each of these perspectives inevitably starts from the premise that the hazards are known, identifiable or quantifiable. In the case of new technologies, this is rarely (if ever) the case. For example, both DDT (a pesticide) and CFCs (a refrigerant) were perceived as effective, safe technological solutions to serious problems of disease (mosquito-borne malaria) and malnutrition or illness (food spoilage). Only later did the systemic environmental consequences of these discoveries become known (for DDT, see for example Metcalf, 1973, and Palumbi, 2001). In fact, discovery of the insecticidal properties of DDT resulted in an award of the Nobel Prize (for medicine, in 1948). Ironically, the only Nobel Prize associated with CFCs was awarded *not* to the discoverer of the chemicals themselves (who was Thomas Midgley, working for General Motors Research Corporation in the 1920s) but instead to the scientists who discovered the deleterious effects of CFCs on the stratospheric ozone layer (F. Sherwood Rowland, Mario Molina and Paul Crutzen for chemistry, in 1995). As the understanding of risk expands to incorporate principles of sustainability, it becomes clearer that the interactions between multiple dimensions of risk are increasingly complex to model quantitatively and the standard approach to risk assessment becomes obsolete.

By contrast, the concept of resilience is detached from the necessity to describe a specific hazard. Resilience is a more general approach to understanding how systems may respond and adapt under stress, such as intrusion of invasive species, outbreak of disease, loss of biomass or release of pollution. In each case, the strategies for recovery in ecological systems can be remarkably similar: e.g., release of reserve resources, reorganization, reproduction, adaptation, migration and evolution. Despite commonality of pathways, the *outcome* of these strategies can be surprising. In transformation, an entirely new system state can result (see, e.g., Holling, 2001). Whereas a traditional risk-based perspective is appropriate for events that can be foreseen or forecasted under a business-as-usual scenario, the resilience perspective is concerned more with organizational response in the event of the *unusual*, unexpected and unforeseen.

On a large scale, industrial systems can also be said to exhibit resilient characteristics. On the scale of a single household, firm or collection of firms constituting an industry, an ecological approach to resilience (e.g. extinction) can be problematic and socially disruptive. From a business perspective, it is the sustainability of the organization that is of paramount importance – not the larger social, economic or environmental system. Nevertheless,

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analogous strategies for resilience are found at the level of a business organization, such as raising new capital, reorganization of the corporate structure, relocation or product redesign. For example, rapidly rising fuel prices and changing consumer preferences have been the impetus behind a recent change in production mix for North American vehicle manufacturers away from light trucks and towards smaller cars. The production changes represent an adaptation in response to the stress of unanticipated changes in the marketplace (i.e. consumer preferences for more fuel efficient vehicles).

It is important to note that there are other examples in which adaptation has been unsuccessful and total transformation of a marketplace has taken place. Note the transformation of communications technology that made telegrams (e.g. Western Union) obsolete and email (e.g. America On Line) ubiquitous. In many cases, the exogenous stressor is technological innovation. Consider the transformation of the dominant retail paradigm in the United States (e.g. Brown *et al.*, 2005). The early dominance of the Woolworths variety store eventually was overshadowed by Sears-Roebuck, which built a reputation based on catalogue shopping (primarily for durable goods) enabled by improvement in transportation technology and infrastructure, and then expanded rapidly by offering free parking to suburban, automobile-based shoppers. Last, Wal-Mart successfully implemented information technology in their supply chain management systems to improve inventory and logistics control that resulted in lower costs. In each case, it may be said that the previously dominant organization lacked the ability to adapt to changing technological and social conditions, resulting in an emergence of a new organization that transformed the system. It may be that in time Wal-Mart's position is also usurped by some other model. It is unlikely, however, that a risk control mentality could have possibly saved any of the business organizations that have been marginalized. In the future, the impetus of change may not come only from technological change, but also from social and environmental change. As the locus of business concern expands from environmental management to sustainable development, so must the basis of environmental strategy expand from a risk to a resilience approach.

Optimization Versus Resilience

The focus of the industrial enterprise has evolved as technology has matured. At the beginning of the industrial revolution, the emphasis was on maximizing throughput. As production increased, returns to scale brought down costs and sales increased, creating a virtuous cycle of growth that rewarded larger and larger production platforms. There was little regard for waste or efficiency, as resources were plentiful. This stage of industrial development was directly analogous to r-type exponential growth in ecological systems operating far from resource constraints (Holling, 2001). However, growth is typically best modelled in the long term as a logistic curve (see, e.g., Modis, 2007). Inevitably, growth slows and sometimes even gives way to collapse.

Later in the industrial revolution, technological improvements in basic industries (such as energy and metals) slowed and production systems began to encounter resource, social and environmental constraints. Emphasis shifted from growth to process optimization – first in economic efficiency and then eco-efficiency. Although the boundaries of optimization in EE are certainly broader than in an exclusively profit maximizing approach, the principal attraction of EE is the close alignment (in many cases) of ecological and economic measures. In any case, the implication of an efficiency mindset is on maximization of desirable measures (and minimization of undesirable). Nonetheless, eco-efficiency may also be merely another stage in the evolution of industrial systems that eventually is superseded by resilience strategies.

For example, it has been written that in Nature nothing is wasted. While the assertion is not precisely true (e.g., the hydrocarbon and phosphate deposits that have driven the agricultural revolution are examples of materials that were *not* cycled by Nature hundreds of millions of years ago), the impression is that material use in ecological systems is extremely efficient. This is especially the case in systems such as coral reefs and tropical forests, where boundary conditions (e.g. climate, chemistry) are extremely stable – allowing for specialization of a diverse array of species to exploit resource niches (see McCann, 2000, also Ring, 1997). In fact, there are analogous studies of economic systems that maintain diversity and resource efficiency, e.g. the energy efficiency comparison of different US states (Templet, 1999, 2004a, 2004b). However, there are processes in ecological systems that are extraordinarily *inefficient*. For example, only some 3% of available low entropy solar energy is utilized by the biosphere (Hukkinen, 2003a). Ecosystem inefficiency is also represented in the poor survival rates of fish eggs, fry

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or young of many species, or the profligate distribution of seeds from plants that are never likely to successfully germinate.

In some cases, the 'waste' represents a risk-reduction strategy. Production of tens of thousands of eggs with a one-in-one-thousand chance of survival might result in a favourable growth rate in the species. Similarly, in financial management, diversification into low-risk investments despite lower reward potential is common practice (see, e.g., Figge, 2005). However, overproduction of eggs (seeds) may also result in rapid exploitation of new environments conducive to the growth and development of young (seedlings) – as can be the case when an invasive species is introduced to an ecological system that lacks natural predators.

In other cases, 'waste' production in ecological systems may result in mutualistic interactions between species that increase system resilience, such as production of nectar by flowers that serves no biological purpose other than to attract insects that will pollinate the flowers (Kearns *et al.*, 1998). Honey production in the hive is evidence that surplus or 'waste' nectar is present. However, in times of stress, the bees may rely on honey stores to ensure survival of the hive and, consequently, the flowers. Plants without a biological mechanism for producing their own energy reserves (e.g. annuals) may reduce the risk of total loss of a reproductive season by producing energy reserves for bees that help buffer disruptions in the system.

Investing in Inefficiency

An analogous interaction exists in industrial ecosystems that exhibit mutualistic symbiosis (see, e.g., Chertow, 2000; Korhonen *et al.*, 2004). 'Waste' production by any individual firm located within an industrial symbiosis network may be desirable from the standpoint of other firms when it is beneficially reused as a resource – even if the economic value of the waste (e.g. waste heat from power generation) is so low as to have little or no price to its seller. Where waste derived fuels or waste derived raw materials substitute for imported fossil fuels or for virgin raw materials at the different manufacturing companies located in the same network of firms, suboptimization of EE measures at the scale of a single firm may result in improved measures at the scale of the entire system. Moreover, the inter-firm linkages may improve cohesion through tacit knowledge exchange (see, e.g., Grant, 2007) and stimulate learning and innovation (Boons, 1998). The result could be enhanced adaptive capacity (i.e. resilience) under conditions of stress.

Further cases of producing surplus or overhead that is more in line with inefficiency than efficiency can be identified in economic systems. International trade relationships tend to be dominated by relatively few industrialized nations. Although greater efficiency in allocation of resources (i.e. cost savings) can result from trade, these gains may come at the expense of reduced adaptability, diversity and resilience (Matutinovic, 2001, 2002). The insignificant or inefficient trade relations may help to better maintain spare production capacity and contribute to insurance against changing and unforeseen developments in the markets.

Also, investments in quantitative inefficiency may enable qualitative transitions from technologies that are currently optimal from an efficiency standpoint to those that are suboptimal from a narrow perspective, but more consistent with principles of sustainability, such as solar energy compared with fossil fuels. Even though the existing technologies for renewables would still be ill equipped to achieve high efficiencies in the processing of materials, in the long run the system and its institutional structures, including the suppliers, customers and other concerned actors, would evolve to a more sustainable state through learning, returns to scale and adaptation. Incorporation of alternative energy sources can enhance resiliency both by slowing the pace of climate change and by introducing technological diversity. In the case of an exclusively eco-efficiency approach, investment will likely be directed into improvement of existing technologies (i.e. adaptation) even if radical change (i.e. transformation) is called for. Therefore, eco-efficiency is only one potentially useful stepping stone in a larger process in accordance with sustainable development.

Local Versus Global Efficiency

It has been a challenge for individual national governments to develop, document, implement and measure nationwide sustainable development programmes. Many countries are in the process. Advanced programmes, e.g. in

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Holland, the UK and Sweden, have been launched. The primary interest of a national sustainable development programme tends to be the environmental and sustainability performance of the country.

Consider global biodiversity concerns. Because of economic growth, timber demand is increasing in China and in Finland. Simultaneously, these countries have decided to enlarge the size of protected forest areas within their territories in their environmental and sustainability programmes. During the last decades, the wood imports to China and to Finland from Russia have increased rapidly. Unlike nature, the economic systems of Western industrialized society in general have been able to substitute local natural limiting factors with imports through international trade (Wackernagel and Rees, 1997). It is commonly known that the Russian forest biodiversity is not protected as carefully as biodiversity of forests in Finland. Inter-national or inter-regional shifting of risks compromises global ecosystem resilience in the long run.

The most striking paradox in this example is the fact that the decline in biodiversity of forests on the Russian side of the border directly affects the biodiversity of the forests in Finland too (Mayer *et al.*, 2005). The migratory patterns of certain species crossing the administrative border between the two countries affect biodiversity, e.g. wolves of Finland depend on the wolves' population inside Russia etc. That is, the international timber trade of this specific case does not only risk sustainability of the global ecosystem as a whole (which indirectly affects the two actual trading partners in question), but it also directly reduces the resilience of the ecosystems of the two trading partners.

In the global biosphere, there are no administrative borders. The global net gain of sustainability programmes is what needs to be looked at. Rich countries and poor countries both must work for the global net gain in sustainability. The efficiency of a national sustainability programme should be measured for its contribution to global sustainable development

Investing in Optimal System Diversity

The vicious cycle of the global socially unsustainable economy encourages poor countries to produce natural resource intensive primary commodities such as timber or fish and rich countries to produce capital intensive products by utilizing the resources of developing countries (Gale, 2000). Poor countries sell their products with low prices to rich countries. The developing world then buys the expensive refined goods from developed nations, following the general thesis of comparative advantage and maximization of its short-term efficiency.

In particular, the developing countries' economies suffer from lack of economic diversity. They need to direct the majority of their resources as well as research and development capacities into rapid production of certain key products. These homogeneous production and product structures are vulnerable, subject to risk and lack resilience in case of change and turbulence. When the economic specialization criterion is extended to ecosystems, man-made single species forest farms or fisheries targeting an individual species replace natural systems that are diverse multispecies ecosystems (Weitzman, 2000). Man-made ecosystems are more subject to diseases and pathogens, because of lack of diversity and resilience.

The criteria for eco-efficiency are temporally dependent, e.g. because scientific knowledge on environmental impacts in ecosystems evolves (Robèrt *et al.*, 2002) and also culturally and socially dependent, e.g., utility and meaning of materials flows is different in different countries (Pongracz, 2002). Preferences and tastes evolve over time subjecting also physical flows to social construction (Norton *et al.*, 1998). The dominant efficiency and eco-efficiency definitions, however, lack a temporal, social and cultural dimension. Current market exchange values are used as the criterion for eco-efficiency.

We suggest that in complex, qualitative, uncertain and dynamic coevolving economic–ecological systems eco-efficiency might actually increase risk, vulnerability and unsustainability. It is important to invest in system diversity, adaptability, flexibility and reserve capacity to preserve resilience. Sustainability matters are inter-organizational (Sinding, 2000; Boons, 1998). Materials and energy flows extend over local, regional and national borders. Cooperation networks benefit from diversity in the actors involved. In the case of one actor leaving the system, the network can recover through diversity when other actors replace the missing function. The dynamics of social constructions imply that currently inefficient behaviour may become efficient in the long term. Maintaining also those activities, functions and actors that are perceived and conceptualized as inefficient now can be

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important for the long-term optimum in sustainable development of complex economic–social–ecological systems.

Conclusion

The most important risks to the sustainability of the human–ecological–industrial complex may not yet be identified. Although climate change is certainly a monumental stressor that may result in transformational change, history teaches us that our ignorance with regard to environmental risk by far exceeds our understanding. Therefore, a risk-based strategy to management of business enterprises, while necessary, is insufficient to ensure progress towards sustainability. We suggest that risk assessment and mitigation efforts be supplemented by investments that enhance system resilience. However, the current emphasis in environmental management on improving eco-efficiency measures may be counter-productive from a resiliency perspective. This may have drastic consequences. In the case of climate change, for example, eco-efficiency improvements may come too late to prevent extraordinary ecological, social and environmental dislocations. In the event that global warming (or some unforeseen catastrophe) is inevitable, the only successful strategy will be adaptation, transformation and evolution. To the extent that eco-efficiency investments embrittle industrial systems to undermine resilience pathways, they may be counter-productive.

This editorial article of the *Business Strategy and the Environment* special issue on 'Strategic sustainability management' has introduced the concept of resilience to business strategy. The editorial shows the limitations and problems in the concept of eco-efficiency, analysed against resilience. Eco-efficiency has become perhaps the most popular concept and tool in corporate environmental and sustainability management and also in environmental policies of public organizations.

We have presented arguments that support investments to what can be defined as inefficiency in terms of the current eco-efficiency literature. Inefficiency may enhance economic system resilience and resilience of affected ecological systems. We find that there are surprisingly many situations where sustainable development benefits from actions and measures that are in line with inefficiency rather than efficiency. We invite corporate environmental and sustainability management scholars as well as environmental policy scholars to further develop research on resilience in business strategy and environmental policy. Critical research and analysis of eco-efficiency policies and management strategies are particularly welcome. Responses to this contribution are encouraged for publication in *Business Strategy and the Environment*.

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