WORKING PAPER

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University of Lüneburg
Working Paper Series in Economics

No. 109

December 2008

www.leuphana.de/vwl/papers

ISSN 1860 - 5508

Institutions and preferences determine resilience of ecological-economic systems

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December 2008

Abstract: We perform a model analysis to study the origins of limited resilience in ecological-economic systems. We demonstrate that the resilience properties of the ecosystem are essentially determined by the management institutions and consumers' preferences for ecosystem services. In particular, we show that complementarity of ecosystem services in human well-being and open access of the ecosystem to profit-maximizing harvesting firms may lead to limited resilience of the ecosystem. We conclude that the role of human preferences and management institutions is not just to facilitate adaptation to, or transformation of, some natural dynamics of ecosystems. Rather, human preferences and management institutions are themselves important determinants of the fundamental dynamic characteristics of the ecological-economic system, such as limited resilience.

JEL-Classification: Q01, Q20, Q57

Keywords: ecological-economic systems, ecosystem services, institutions, natural resource management, preferences, resilience

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1 Introduction

Natural systems that are used and managed by humans for the ecosystem services they provide may exhibit non-trivial dynamics. This makes the long-term conservation and sustainable use of such systems a huge challenge.

In particular, a system may be characterized by limited resilience (Holling 1973). That is, it exhibits multiple stability domains ("basins of attraction") that differ in fundamental system structure and controls as well as in the level and quality of ecosystem services provided to humans. These stability domains are separated by thresholds in the system's state variables. As a result of exogenous natural disturbances or ill-adapted human interference with the system, the system may flip from one stability domain into another one with different basic functions and controls (Holling 1973, Levin et al. 1998, Carpenter et al. 2001, Scheffer et al. 2001). Examples encompass a diverse set of ecosystem types that are highly relevant for economic use, such as boreal forests, semi-arid rangelands, wetlands, shallow lakes, coral reefs, or high-seas fisheries (Gunderson and Pritchard 2002).

As the system undergoes a regime shift and flips from one basin of attraction with more desirable ecosystem service provision (from the anthropocentric point of view based on valuation of ecosystem services) to a basin of attraction with less desirable ecosystem service provision, humans will assess this change as a deterioration in ecosystem service provision, or even as a "catastrophic" shift (Scheffer et al. 2001). Such system flips may threaten the intertemporal efficiency of resource management and the intergenerational equity of ecosystem services use from this system, and may thus impair a sustainable development (Arrow et al. 1995, Perrings 2001, 2006, Derissen et al. 2008, Mäler 2008).

Many studies analyzing the role of resilience for the long-term development of ecological-economic systems explain limits to resilience, i.e. the existence of multiple basins of attraction in a dynamic system that are separated by thresholds in the system's state space, by *natural* characteristics of the system which exist prior to any human interference with the system, such as e.g. ecological properties of shallow lakes or the interaction between grass and shrub species in semi-arid rangelands. Human management of the system then has to be adapted to this natural characteristic, or transform the dynamic characteristics of the natural system, so as to achieve sustainability (e.g. Berkes and Folke 1998, Gunderson et al. 2001, Berkes et al. 2002).

In this paper, we want to point out that limits to a system's resilience, i.e. the existence of multiple basins of attraction, are not necessarily an originally ecological characteristic of the system, but they may as well be induced into the system's dynamics only by particular forms of human management and economic use of the system.

For that sake, we present a model of a simple multi-species ecosystem that may, but does not need to be, harvested for economic purposes, such as profit-maximization of resource-extracting firms or optimal satisfaction of resource consumers' demand. For the clarity of the argument, the model ignores any biological interactions of the species. In the absence of any economic use or management, the ecosystem thus exhibits very simple dynamics: there is only one single globally stable equilibrium and, consequently only one single basin of attraction. In other words, the system is absolutely resilient to any exogenous disturbance.[1] We show that, in contrast, when species are harvested for economic purposes and are complementary in human well-being, the system exhibits multiple locally stable equilibria and, consequently, multiple basins of attraction that are separated by thresholds in state space. In other words, in the domain of attraction that is desirable from an anthropocentric point of view (motivated by the valuation of ecosystem services), the system exhibits only limited resilience and may flip into another, less desirable, domain of attraction due to some exogenous disturbance. We also analyze how the resilience properties of the ecological-economic system,

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[1] Of course, there exist natural systems that exhibit non-linear dynamics and, consequently, limited resilience. The reason why we are starting from a natural ecosystem model with very simple dynamics is purely analytical: we want to show that limited resilience in the system's dynamics may be a consequence of economic use or management.

which are induced solely by human management of the system, depend on the management institutions and consumers' preferences for ecosystem services.

2 Model

Consider the following model, which gives a highly stylized, yet fully encompassing and general description of dynamic ecological-economic systems. Society consists of n identical and utility-maximizing individuals who derive utility from the consumption of manufactured goods (y) and two different ecosystem services, say fish (c) and timber (h). Assuming that all three goods are essential for individual well-being and that the two ecosystem services are complementary in human well-being, the utility of a representative household can be described by the utility function

$$u(y,c,h) = y^{1-\alpha} \left[c^{\frac{\sigma-1}{\sigma}} + h^{\frac{\sigma-1}{\sigma}} \right]^{\alpha \frac{\sigma}{\sigma-1}} , \tag{1}$$

where $\alpha \in (0,1)$ is the representative household's elasticity of marginal utility of ecosystem services and $0 \leq \sigma < 1$ is the elasticity of substitution between the consumption of fish and timber. A smaller value of σ thereby implies a higher degree of complementarity of fish and timber. In the limit $\sigma \to 0$, fish and timber would be perfect complements and utility would be determined by the relatively scarcer ecosystem service only.

The dynamics of the stocks of fish (x) and wood (w) are described by the following system of differential equations

$$\begin{aligned} \dot{x} &= f(x) - C \quad \text{and} & (2) \\ \dot{w} &= g(w) - H \ , & (3) \end{aligned}$$

where the functions $f(\cdot)$ and $g(\cdot)$ describe the intrinsic growth of the stocks of fish and wood, and C and H denote the aggregate amounts of fish and timber harvested. The differential Equations (2) and (3) are independent because, by assumption, the two species are ecologically independent. Although, of course, in reality there may exist ecological interactions between the two resource species, here we assume complete independence for purely analytical reasons: While it is well known that ecological interactions may give rise to non-trivial resilience properties, here we want to demonstrate that such dynamic properties of an ecological system may also result in the absence of any ecological interactions from particular institutions of resource management or human preferences about resource consumption.

For expositional simplicity, we specify $f(\cdot)$ and $g(\cdot)$ as logistic growth functions:

$$f(x) = \rho_x \left(1 - \frac{x}{\kappa_x}\right) x \quad \text{and} \tag{4}$$

$$g(w) = \rho_w \left(1 - \frac{w}{\kappa_w}\right) w \ , \tag{5}$$

where ρ_i denotes the intrinsic growth rate and κ_i the carrying capacity of the stocks of fish ($i = x$) and wood ($i = w$), respectively. The specification of logistic growth functions is by no means essential for the results derived below. But using a well-known functional form of the growth functions $f(x)$ and $g(w)$ helps to clarify the argument and to highlight the role of preferences and institutions for the dynamics of the ecological-economic system.

There are m_x identical fish-harvesting firms and m_w identical timber-harvesting firms. These numbers are endogenously determined according to market conditions in these two sectors. Let e_x and e_w denote the effort, measured in units of labor, spent by some representative fish-harvesting-firm and some representative timber-harvesting-firm. The maximum amounts of fish and timber that can be harvested from the respective stocks by individual firms are described by Gordon-Schaefer production functions

$$c^{\text{prod}} = \nu_x \, x \, e_x \ , \tag{6}$$

$$h^{\text{prod}} = \nu_w \, w \, e_w \ , \tag{7}$$

where ν_x and ν_w denote the productivity of harvesting fish and timber, respectively. Then, the aggregate amounts of fish and timber harvested are simply

$$C = m_x \, c^{\text{prod}} \quad \text{and} \tag{8}$$

$$H = m_w \, h^{\text{prod}} \ . \tag{9}$$

Assume that each household inelastically supplies one unit of labor, so that total labor supply of the economy is equal to human population size n, and that labor markets are perfectly competitive. Households work either in one of the resource harvesting sectors or in the manufactured-goods sector. Assuming that labor is the only factor input for the production of manufactured goods, and that production is through a constant-returns-to-scale technology, i.e. each unit of labor produces $\omega > 0$ units of output, aggregate output of manufactured goods is

$$Y = \omega \, (n - m_x \, e_x - m_w \, e_w) \tag{10}$$

and the (constant) competitive wage rate is equal to the marginal product of labor, ω.

3 Analysis

We analyze the resilience properties of the ecological-economic system for different scenarios in terms of resource-management institutions and preferences about ecosystem services. For that sake we employ local and global stability analysis based on graphical representation of the system's dynamics in state space.[2]

3.1 Natural dynamics: unlimited resilience

In the absence of any natural resource use by society, the system's dynamics is completely determined by the natural dynamics of the two resources stocks of fish and wood, described by Equations (2)–(5) with $C = H = 0$. Since the dynamics of the two resource stocks are independent of each other, in the absence of any harvest both stocks converge to their respective carrying capacity. The isoclines $\dot{x} = 0$ and $\dot{w} = 0$ thus are the straight lines with $w = \kappa_w$ and $x = \kappa_x$, respectively. This dynamics is represented by the state-space diagram shown in Figure 1 for parameter values $\rho_x = \rho_w = 0.5$ and $\kappa_x = \kappa_w = 1$. The green line is the isocline

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[2] All statements could as well be proved analytically, so that it becomes obvious that our qualitative statements hold true independent of the parameter values used for graphical illustration.

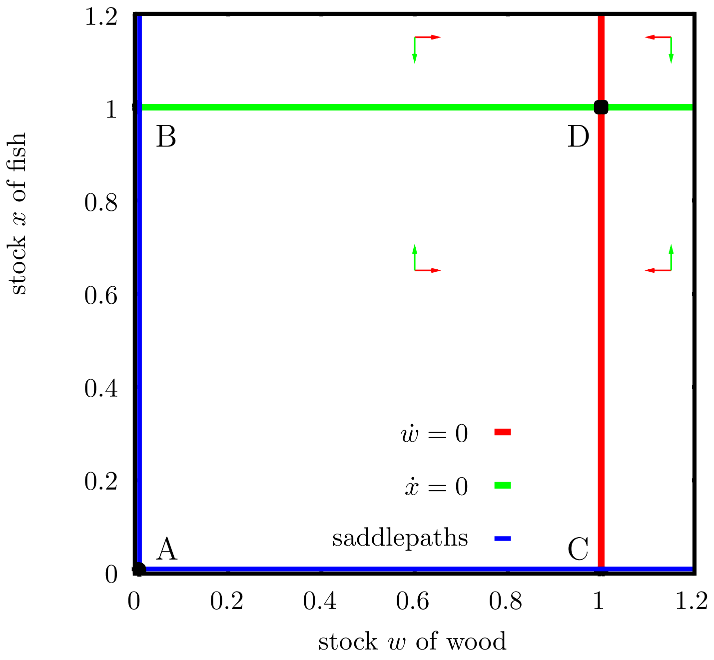

Figure 1: Phase diagram for the ecosystem's natural dynamics without any harvest. Dynamics is characterized by $\dot{x} > 0$ (< 0) below (above) the green line, and $\dot{w} > 0$ (< 0) left (right) of the red line. A is an unstable equilibrium, B and C are locally saddlepoint stable equilibria. D is the only and (almost) globally stable equilibrium; the corresponding basin of attraction comprises the entire state space with the exception of points A, B and C. Parameter values: $\rho_x = \rho_w = 0.5$, $\kappa_x = \kappa_w = 1$.

for $\dot{x} = 0$, the red line is the isocline for $\dot{w} = 0$. Below (above) the $\dot{x} = 0$-isocline the dynamics is characterized by $\dot{x} > 0$ (< 0). Likewise, left (right) of the $\dot{w} = 0$-isocline the dynamics is characterized by $\dot{w} > 0$ (< 0). In each segment of state space, the green and red arrows indicate this direction of dynamics. At the intersection of the isoclines (point D: $x = 1$, $w = 1$), one has $\dot{x} = \dot{w} = 0$ and from the arrows it becomes obvious that this is a stable equilibrium.

Other than D, the system has three more equilibria: A ($x = w = 0$),B ($x = 1$, $w = 0$) and C ($x = 0$, $w = 1$). From the state-space representation (Figure 1) it is obvious that A is an unstable equilibrium, while B and C are locally saddlepoint stable equilibria. From the point of view of social desirability, equilibrium D is clearly superior to equilibria A, B and C because the latter are characterized by non-existence of one (C) or the other (B) or both (A) of the resource species and the corresponding ecosystem service so that utility (Equation 1) is zero and, thus, minimal.

In terms of stability, D is the only stable equilibrium of the system. The corresponding stability domain ("basin of attraction") comprises the entire state space with the exception of points A, B and C. From any system state in that domain will the system automatically converge towards equilibrium D. So, equilibrium D is (almost) globally stable – where the "almost" refers to the exception of three single system states (A, B, C) none of which is stable.[3] In terms of resilience, the natural system is therefore characterized by (almost) unlimited resilience.

3.2 Institutions: Profit-maximizing harvesting under open access to ecosystems significantly weakens resilience

We demonstrate that institutions of resource management can significantly alter the resilience properties of an ecosystem by giving an example of an institution that significantly weakens resilience of the ecosystem. Suppose that profit-maximizing firms can harvest the resource species from their natural stocks under open-access to ecosystems, and sell these ecosystem services as market products to consumers.

Taking manufactured goods as the numeraire, the representative household's utility maximization problem is

$$\max_{y,c,h} u(y,c,h) \quad \text{subject to} \quad \omega = y + p_x\, c + p_w\, h \ , \tag{11}$$

where p_x and p_w are the market prices of fish and timber, respectively. With utility

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[3] The exceptions to the global stability domain form a set of Lebegue measure zero.

function (1), this leads to Marshallian demand functions for fish and timber:

$$c(p_x, p_w, \omega) = \alpha\, \omega\, \frac{p_x^{-\sigma}}{p_x^{1-\sigma} + p_w^{1-\sigma}} \quad \text{and} \tag{12}$$

$$h(p_x, p_w, \omega) = \alpha\, \omega\, \frac{p_w^{-\sigma}}{p_x^{1-\sigma} + p_w^{1-\sigma}} \ . \tag{13}$$

Profits of representative firms harvesting fish and timber are given by

$$\pi_x = p_x\, c^{\text{prod}} - \omega\, e_x = \left(p_x\, \nu_x\, x - \omega\right)\, e_x \qquad \text{and} \tag{14}$$

$$\pi_w = p_w\, h^{\text{prod}} - \omega\, e_w = \left(p_w\, \nu_w\, w - \omega\right)\, e_w \ , \tag{15}$$

where production functions (6) and (7) have been employed in the second equality. In open-access equilibrium, which is characterized by zero profits, i.e. $\pi_x = 0$ and $\pi_w = 0$ for all firms, we thus have the following relationships between equilibrium market prices and resource stocks of fish and wood:

$$p_x = \frac{\omega}{\nu_x}\, x^{-1} \quad \text{and} \tag{16}$$

$$p_w = \frac{\omega}{\nu_w}\, w^{-1} \ . \tag{17}$$

Inserting these expressions into demand functions (12) and (13), we obtain open-access per-capita resource demands of fish and timber as functions of the respective resource stocks:

$$c(x, w) = \alpha\, \frac{\left(\nu_x\, x\right)^{\sigma}}{\left(\nu_x\, x\right)^{\sigma-1} + \left(\nu_w\, w\right)^{\sigma-1}} \quad \text{and} \tag{18}$$

$$h(x, w) = \alpha\, \frac{\left(\nu_w\, w\right)^{\sigma}}{\left(\nu_x\, x\right)^{\sigma-1} + \left(\nu_w\, w\right)^{\sigma-1}} \ . \tag{19}$$

General market equilibrium, when aggregate supply equals aggregate demand on the markets for both ecosystem services, is characterized by the conditions

$$C = m_x\, c^{\text{prod}} = nc(x, w) \quad \text{and} \tag{20}$$

$$H = m_w\, h^{\text{prod}} = nh(x, w) \ . \tag{21}$$

Inserting these market-clearing-conditions into Equations (2) and (3), the dynamics of the ecological-economic system in a general market equilibrium where profit-maximizing harvesting firms have open access to ecosystems is described by the following system of coupled differential equations:

$$\dot{x} = f(x) - nc(x, w) \quad \text{and} \tag{22}$$

$$\dot{w} = g(w) - nh(x, w) \ . \tag{23}$$

This dynamics is represented by the state-space diagram shown in Figure 2 for parameter values $\rho_x = \rho_w = 0.5$, $\kappa_x = \kappa_w = 1$, $\nu_x = \nu_w = 1$, $\alpha = 0.6$, $\sigma = 0.4$ and $n = 1$. Again, the green line is the isocline for $\dot{x} = 0$, the red line is the isocline for

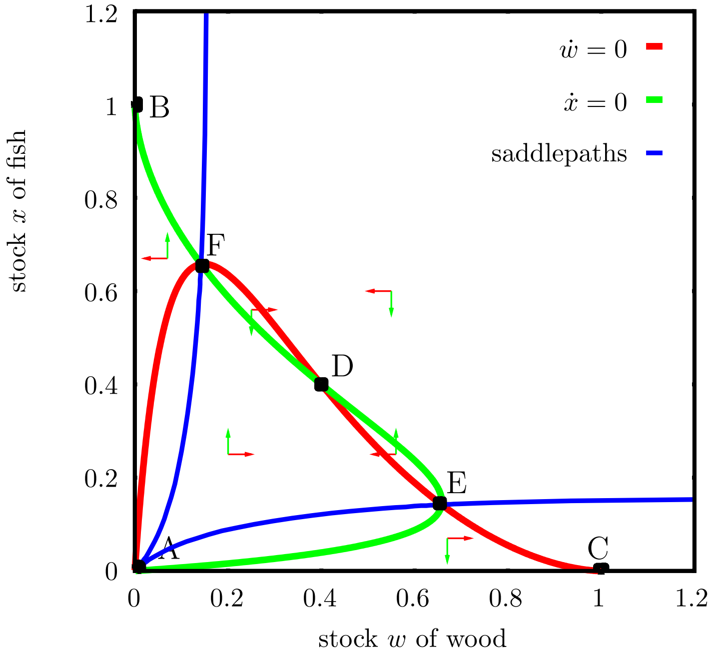

Figure 2: Phase diagram for the ecosystem's dynamics under open access and profit-maximizing harvesting. Dynamics is characterized by $\dot{x} > 0$ (< 0) left (right) of the green line, and $\dot{w} > 0$ (< 0) below (above) the red line. A is an unstable equilibrium; E and F are locally saddlepoint stable equilibria; B, C and D are locally stable equilibria; the corresponding basins of attraction are the area northeast of the upper saddlepath (for B), the upper saddlepath (for F), the area in between the two saddlepaths (for D), the lower saddlepath (for E), and the area southwest of the lower saddlepath (for C). Parameter values: $\rho_x = \rho_w = 0.5$, $\kappa_x = \kappa_w = 1$, $\nu_x = \nu_w = 1$, $\alpha = 0.6$, $\sigma = 0.4$, $n = 1$.

$\dot{w} = 0$. Left (right) of the $\dot{x} = 0$-isocline the dynamics is characterized by $\dot{x} > 0$ (< 0). Likewise, below (above) the $\dot{w} = 0$-isocline the dynamics is characterized by $\dot{w} > 0$ (< 0). In each segment of state space, the green and red arrows indicate this direction of dynamics.

Compared to the scenario without human resource use (cf. Figure 1), the stability properties of the ecosystem are now fundamentally altered. While A ($x = w = 0$) is still an unstable equilibrium, B ($x = 1$, $w = 0$) and C ($x = 0$, $w = 1$) are now locally stable equilibria. D is still a stable equilibrium, but it is now only locally stable. In addition, there are two new equilibria, E and F, which are locally saddlepoint stable. The stability domains ("basins of attraction") associated with the stable equilibria are as follows: for the saddlepoint stable equilibrium E it is the saddlepath associated with E; for the saddlepoint stable equilibrium F it is the saddlepath associated with F; for the locally stable equilibrium B it is the area northeast of the saddlepath associated with F; for the locally stable equilibrium C it is the area southwest of the saddlepath associated with E; and for the locally stable equilibrium D it is the area in between the two saddlepaths.

It is obvious that the particular resource management institution considered here as an example – open access to ecosystems of profit-maximizing harvesting firms – has fundamentally altered the resilience properties of the ecosystem. While in the absence of human resource use there exists only one (almost) globally stable equilibrium with (almost) unlimited resilience, the ecosystem has three locally stable equilibria under open access to ecosystems of profit-maximizing harvesting firms. Each of those has an associated stability domain ("basin of attraction") which comprises only a limited part of the state space, so that the system may flip from one basin of attraction to another one as a result of exogenous disturbance. In particular, the equilibrium D (with both resource species in existence) has now only limited resilience, and the system may be disturbed in a way that it flips into another basin of attraction with another locally stable equilibrium characterized by extinction of one or the other species.

3.3 Insitutions: Optimal harvesting by a sole owner or regulator increases resilience

As we have demonstrated in the previous section, profit-maximizing harvesting under open access to ecosystems weakens resilience of the ecological-economic system compared to the case without harvesting. But also when harvesting takes place, resilience of the system may be increased by a change in the institutional setting. In order to illustrate this point, we consider the example of optimal resource use, which may be implemented through the institutional setting that a sole owner or regulator determines and implements the optimal harvesting of fish and timber.[4]

The optimization problem is to choose total harvest of fish (C) and timber (H), as well as consumption of the manufactured good (y) such as to maximize intertemporal welfare,

$$\max_{y,C,H} \int_0^\infty u(y,C,H)\, e^{-\delta t}\, dt \qquad \text{subject to} \tag{24}$$

$$y = \omega \left(1 - \frac{C}{\nu_x\, x} - \frac{H}{\nu_w\, w}\right) \tag{25}$$

$$\dot{x} = f(x) - C \tag{26}$$

$$\dot{w} = g(w) - H\ . \tag{27}$$

Here, we assume a positive discount rate $\delta > 0$. This optimization problem is solved in the standard way by considering the current-value Hamiltonian

$$\mathcal{H} = y^{1-\alpha} \left[C^{\frac{\sigma-1}{\sigma}} + H^{\frac{\sigma-1}{\sigma}}\right]^{\alpha \frac{\sigma}{\sigma-1}} + \lambda \left[\omega \left(1 - \frac{C}{\nu_x\, x} - \frac{H}{\nu_w\, w}\right) - y\right] + \mu_x\, [f(x) - C] + \mu_w\, [g(w) - H]\ , \tag{28}$$

where λ is the shadow price of the manufactured good, μ_x is the shadow price of the fish stock and μ_w is the shadow price of the stock of wood. The first-order

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[4] For simplicity, we normalize population to unity in this section following, i.e. we set $n = 1$.

conditions for the optimization problem (24) are as follows

$$\frac{1-\alpha}{y}\,u(y,C,H) = \lambda \tag{29}$$

$$\frac{\alpha\,C^{-\frac{1}{\sigma}}}{C^{\frac{\sigma-1}{\sigma}}+H^{\frac{\sigma-1}{\sigma}}}\,u(y,C,H) = \lambda\,\frac{\omega}{\nu_x\,x}+\mu_x \tag{30}$$

$$\frac{\alpha\,H^{-\frac{1}{\sigma}}}{C^{\frac{\sigma-1}{\sigma}}+H^{\frac{\sigma-1}{\sigma}}}\,u(y,C,H) = \lambda\,\frac{\omega}{\nu_w\,w}+\mu_w \tag{31}$$

$$\lambda\,\frac{\omega\,C}{\nu_x\,x^2} = [\delta - f'(x)]\;\mu_x - \dot{\mu}_x \tag{32}$$

$$\lambda\,\frac{\omega\,H}{\nu_w\,w^2} = [\delta - g'(w)]\;\mu_w - \dot{\mu}_w\ . \tag{33}$$

The easiest way to gain insights into the optimal dynamics of the ecological-economic system is to consider the optimal steady state. The steady-state values for the stocks of fish and wood and the harvest of fish and timber are characterized by the following four conditions

$$C = f(x) \tag{34}$$

$$H = g(w) \tag{35}$$

$$\frac{\omega\,C}{\nu_x\,x^2} = [\delta - f'(x)]\left[\frac{\alpha}{1-\alpha}\,\frac{y\,C^{-\frac{1}{\sigma}}}{C^{\frac{\sigma-1}{\sigma}}+H^{\frac{\sigma-1}{\sigma}}} - \frac{\omega}{\nu_x\,x}\right] \tag{36}$$

$$\frac{\omega\,H}{\nu_w\,w^2} = [\delta - g'(w)]\left[\frac{\alpha}{1-\alpha}\,\frac{y\,H^{-\frac{1}{\sigma}}}{C^{\frac{\sigma-1}{\sigma}}+H^{\frac{\sigma-1}{\sigma}}} - \frac{\omega}{\nu_w\,w}\right]\ . \tag{37}$$

For the parameter values used in the example of the previous section (see caption of Figure 2) and for a reasonably low discount rate, the optimal steady state is unique.. Hence, under optimal regulation, the dynamics are characterized by an (almost) globally stable steady state. Figure 3 shows how the optimal steady-state level of the stock of fish varies with the discount rate.

3.4 Preferences: Substitutability among ecosystem services in consumption increases resilience

Besides the institutional setting, human preferences about ecosystem services and manufactured goods are a significant determinant of an ecosystem's resilience prop-

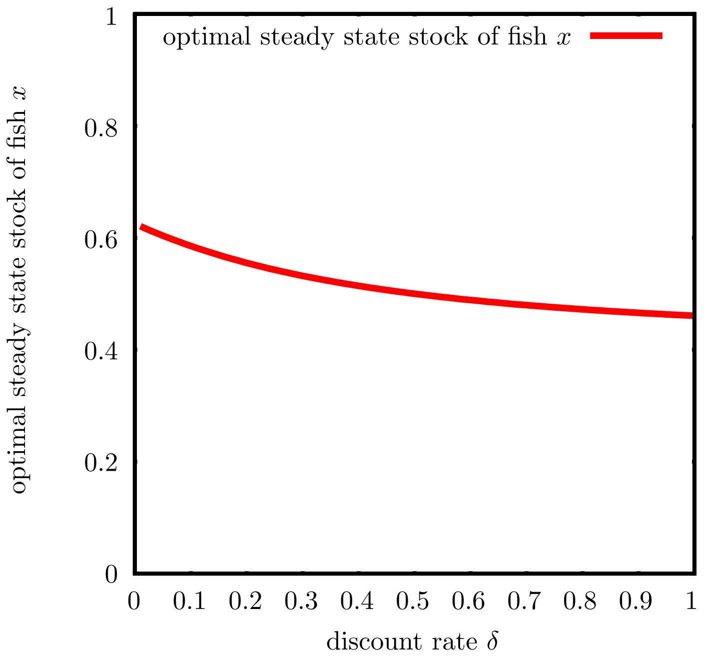

Figure 3: Optimal steady state level of the stock of fish for varying discount rate. The steady state is unique for the whole range of discount rates. Parameter values: $\rho_x = \rho_w = 0.5$, $\kappa_x = \kappa_w = 1$, $\nu_x = \nu_w = 1$, $\alpha = 0.6$, $\sigma = 0.4$, $n = 1$. Due to the identical parameter values assumed in this example, the steady state stock of wood is equal to the steady state stock of fish.

erties. This is demonstrated here by illustrating for the institutional setting considered in the previous section – open access to ecosystems of profit-maximizing harvesting firms – how a change in the elasticity of substitution between the consumption of fish and timber affects the stability properties of the ecosystem.

The analysis in the previous subsection was carried out for an elasticity of substitution between the consumption of fish and timber of $\sigma = 0.4$, which reflects a mild complementarity. Figures 4 and 5 illustrate the stability properties of the ecosystem when – everything else being equal – the elasticity of substitution changes to $\sigma = 0.95$ (low complementarity) and $\sigma = 0.05$ (high complementarity), respectively.

From Figure 4 it is apparent that even for open access and profit-maximizing

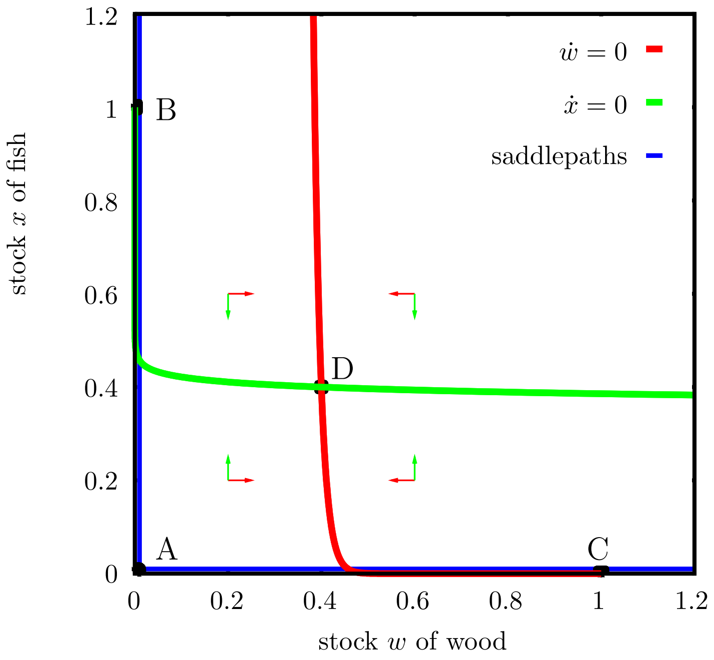

Figure 4: Phase diagram for the ecosystem's dynamics under open access and profit-maximizing harvesting. Dynamics is characterized by $\dot{x} > 0$ (< 0) below (above) the green line, and $\dot{w} > 0$ (< 0) left (right) of the red line. A is an unstable equilibrium, B and C are locally saddlepoint stable equilibria. D is the only and (almost) globally stable equilibrium; the corresponding basin of attraction comprises the entire state space with the exception of points A, B and C. Parameter values: $\rho_x = \rho_w = 0.5$, $\kappa_x = \kappa_w = 1$, $\nu_x = \nu_w = 1$, $\alpha = 0.6$, $\sigma = 0.95$, $n = 1$.

resource harvesting, with low complementarity between ecosystem services in consumption the resilience of the system is relatively high. The stability properties of the system are basically the same as in the natural state, i.e. without human resource management, while the location of the stable equilibrium D in state space has shifted quite a bit due to resource harvesting (cf. Figure 1).

With increasing complementarity between the two ecosystem services in consumption, i.e. decreasing value of σ, the resilience of this equilibrium reduces (cf. Figure 2 and the discussion in the previous section). At a certain threshold value of σ ($\sigma = 1/3$ for the parameter values used to compute the figures) the locally stable equilibrium D in Figures 1, 2 and 4 looses its stability and turns into an only saddlepoint-stable equilibrium (Figure 5). The stability domain ("basin of attraction") for this equilibrium is just a one-dimensional line. This means, its resilience is extremely reduced and the system is very brittle and sensitive to exogenous disturbance.

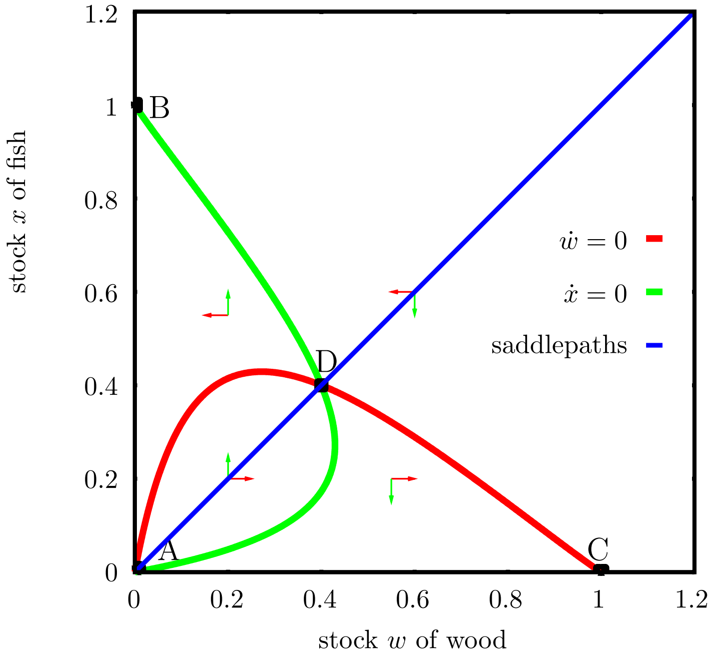

Figure 5: Phase diagram for the ecosystem's dynamics under open access and profit-maximizing harvesting. Dynamics is characterized by $\dot{x} > 0$ (< 0) left (right) of the green line, and $\dot{w} > 0$ (< 0) below (above) the red line. A is an unstable equilibrium; B, C and D are locally saddlepoint-stable equilibria; the stability domain for each of those equilibria is just a one-dimensional line. Parameter values: $\rho_x = \rho_w = 0.5$, $\kappa_x = \kappa_w = 1$, $\nu_x = \nu_w = 1$, $\alpha = 0.6$, $\sigma = 0.05$, $n = 1$.

The general insight from the analysis in this section is that resilience of the interior equilibrium with both resource species in existence (D) tends to decrease with increasing complementarity, i.e. decreasing elasticity of substitution, between the two ecosystem services in human well-being. In other words, while complementarity of ecosystem services in human well-being destabilizes an ecosystem, substitutability of ecosystem services in human well-being tends to make the natural resource systems that provide these services more resilient.

4 Conclusion

Our analysis has demonstrated that the role of human preferences and management institutions is not just to facilitate adaptation to, or transformation of, some natural dynamics of ecosystems, but that they are themselves important determinants of the dynamic characteristics of the ecological-economic system, such as limited resilience.

In particular, we have shown that complementarity of ecosystem services in human well-being significantly reduces the resilience of ecosystems when profit-maximizing harvesting firms have open access to ecosystems. This is due to the following de-stabilizing effect: out of two complementary ecosystem services, the scarcer one is limiting the benefits from ecosystem service use. Hence, under an institutional setting of open access, this ecosystem service is the one to which harvest is directed primarily. The increased harvesting effort, in turn, reduces the abundance of that resource even further, thus leading to self-re-enforcing dynamics. Put the other way round, this means that substitutability of ecosystem services in consumption tends to make the ecosystems that provide these services more resilient.

In the joint endeavor of natural and social scientists as well as practitioners of resource management to understand and manage ecological-economic systems for sustainability, our results call for truly interdisciplinary and integrated analysis of such systems and their management.

Acknowledgments

We are grateful to the German Federal Ministry of Education and Research for financial support under grant no. 01UN0607.

References

Arrow, K.J., B. Bolin, R. Costanza, P. Dasgupta, C. Folke, C.S. Holling, B.-O. Jansson, S. Levin, K.-G. Mäler, C. Perrings and D. Pimentel (1995), Economic growth, carrying capacity, and the environment, *Science*, **268**(5210): 520–521.

Berkes, F. and C. Folke (eds) (1998), *Linking Social and Ecological Systems. Management Practices and Social Mechanisms for Building Resilience*, Cambridge University Press, Cambridge.

Berkes, F., J. Colding and C. Folke (eds) (2002), *Navigating Social-Ecological Systems: Building Resilience for Complexity and Change*, Cambridge University Press, Cambridge.

Carpenter, S.R., B. Walker, J.M. Anderies and N. Abel (2001), From metaphor to measurement: resilience of what to what? *Ecosystems*, **4**: 765–781.

Derissen, S., M.F. Quaas and S. Baumgärtner (2008), Resilience and sustainable development of ecological-economic systems, *Working Paper*, University of Kiel.

Gunderson, L.H. and C.S. Holling (eds) (2001), *Panarchy. Understanding Transformations in Human and Natural Systems*, Island Press, Washington DC.

Gunderson, L.H. and L. Pritchard Jr. (eds) (2002), *Resilience and the Behavior of Large-Scale Systems*, Island Press, Washington DC.

Holling, C.S. (1973), Resilience and stability of ecological systems, *Annual Review of Ecology and Systematics*, **4**: 1–23.

Levin, S.A., S. Barrett, S. Aniyar, W. Baumol, C. Bliss, B. Bolin, P. Dasgupta, P. Ehrlich, C. Folke, I.-M. Gren, C.S. Holling, A.-M. Jansson, B.-O. Jansson, D. Martin, K.-G. Mäler, C. Perrings and E. Sheshinsky (1998), Resilience in natural and socioeconomic systems, *Environment and Development Economics*, **3**(2): 222–234.

Mäler, K.-G. (2008), Sustainable development and resilience in ecosystems, *Environmental and Resource Economics*, **39**: 17–24.

Perrings, C. (2001), Resilience and sustainability, in H. Folmer, H.L. Gabel, S. Gerking and A. Rose (eds.), *Frontiers of Environmental Economics*, Edward Elgar, Cheltenham, pp. 319–341.

Perrings, C. (2006), Resilience and sustainable development, *Environment and Development Economics*, **11**(4): 417–427.

Scheffer, M., S. Carpenter, J.A. Foley, C. Folke and B. Walker (2001), Catastrophic shifts in ecosystems, *Nature*, 413: 591–596.

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