Original Research

Systems Dynamics in Modeling Sustainable Management of the Environment and Its Resources

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Abstract

This article was inspired by the predator-prey relationship, a common concept in ecology. Using it as our basis, we present a study on the subject of economic growth linked to the consumption of environmental resources. Various economy-environment development scenarios are examined using the dynamics method and STELLA software. Isomorphisms (i.e. structural similarities) between the two systems allow us to conclude that both growing economic savings and effectiveness, as well as higher outlays for initiatives aimed at offsetting deficiencies and enriching environmental potential, may not reverse the cyclical growth trend of the system examined. While attempting to discuss sustainable development at present, a thorough change in management paradigms should be considered. If an environmental system is acted upon, its life should be sustained. Truly lasting economic and environmental growth is based on drawing benefits from life-giving feedback.

Keywords: systems dynamics, sustainable development, predator-prey relationship, management of the environment

Introduction

For more than a quarter century, the economy-environment dynamic has been subject to concepts of an ongoing development in order to balance the needs of the environment and humans. Parallel to the release of *World Conservation Strategy* [1] in 1980, this paradigm became a fixture in concepts concerned with the management of the environment and its resources. Despite this, instances of alarming abuse, excessive pressure on the environment, and its devastation on a grand scale may still be noted – especially in developing countries. Most frequently, these instances are triggered by a pursuit of prosperity and the longing for economic growth noted by the wealthiest coun-

tries in the world [2, 3]. Sadly, they are often accompanied by the lack of perspective thinking and no ecological awareness on the part of communities and their ruling elites. However, barriers of ignorance or insensitivity to the issues of ecology may not be tolerated or left to themselves. They should be overcome and should trigger a more in-depth reflection on the part of the communities that mismanage the environment. Such attempts had been made a long time before the concept of sustainable development was formulated.

In 1972, *Limits to Growth* was published. Dennis Meadows, its co-author, presented results contained in the book to an association of economists, politicians, and scientists affiliated with the Club of Rome. The conclusions stirred quite a commotion and had a powerful international response. As a result of Meadows' report, the realistic threat

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of a global cataclysm was brought to attention, very likely for the first time. The model presented in the report assumes a reserve of 250 years for all tangible resources at their 1970 consumption rate. As they run out, the global system should collapse within the following 100 years, postulates Meadows. A drastic drop in global production would be noted, followed by massive unemployment, reduction in food production, and a marked increase in fatality rates [4]. Unfortunately, even if the number of non-renewable resources is doubled, the result would be catastrophic as the crisis may not be halted by simply eliminating an inevitable deficit of resources. As long as the manner and methods of management are not changed, and as long as the set of values and a consumption-oriented lifestyle are not reviewed, humans will cause excessive deterioration of the natural environment and will face yet another barrier, states Michnowski [5], citing the above thesis. Polish language literature also features references to Meadow's report, made by Domański [6] and Kuciński [7]. The authors stress that arbitrary removal of barriers related to resources and the environment creates a new issue. Computer simulations indicate that human population would grow at such a fast pace that it would encounter the problem of reaching the ceiling while increasing food production. Skeptics who believe that such abstract models do not have much in common with real life should be referred to an updated version of the report, titled *Beyond the Limits* [8]. The only departure from the reality as outlined 20 years prior consists in still greater dynamics of some adverse processes occurring in that complex meta-system, Michnowski [5] and Schultink [9] conclude while commenting on *Beyond the Limits*.

Developed according to the systems dynamics concept, the Meadows' model assumes the presence of feedback. The phenomena were promoted by Ludwig von Bertalanffy, creator of the general systems theory and a Vienna-based biologist, as early as the 1930s. The Meadows' model simplifies a complex reality (the very essence of modeling). Thanks to the occurrence of feedback, it explains the essence of key phenomena that take place in global the economy, which disperses and consumes environmental resources at an increasing rate, thus contributing to its greater entropy.

One of the key assumptions of the general systems theory is the isomorphic nature of laws across various fields of science. In this context, Bertalanffy [10] refers to pioneering reports by Lotka and Volterra in his breakthrough work since the dynamics theory in biological populations, struggle for survival, and biological balance are examples of a high-level theory which postulates mutual interactions of beings and forces. According to Kuciński [7], a certain type of an analogy and empirical confirmation of laws reported within a given field that is systemic in nature may be anticipated in a different field, if systems that meet the criteria of the 'system' definition occur there. Therefore, laws identified in nature or physics may also guide processes that occur in the economy and its interactions with the surroundings. This is the assumption put forward by Bajerowski [11], who says, the relationship between the

environment and the economy may be simulated perfectly well using an ecology-inspired dynamic model. It describes growth cycles noted in 1926 in the predator-prey relationship by V. Volterra. The model, once implemented to define the economy-environment relationship, advises a far-fetched caution in exploiting the environment and its resources. It implicates that initiatives driven by economic goals while accompanying ecological costs are of secondary importance, resulting in the economy linking to an over-exploited environment facing losses in the future. The losses may be deferred and may vary in the level of their severity. However, they are inevitable as long as a thorough change of goals, principles, and growth priorities, followed by dematerialization and upgrading of the economy, does not take place. This article elaborates on considerations put forward by Bajerowski [11]. A study of behaviors in a dynamic system composed of aggregated economic and ecological values has been conducted according to the system dynamics method.

Methodology

The concept that is contemporarily known as 'systems dynamics' was developed by J. Forrester, a U.S. scientist in the late 1950s [12]. Systems dynamics was promptly popularized outside the United States, while the range of its applications encompassed a broad category of social issues. A meeting between Forrester and members of the Club of Rome resulted in an initiative to develop a dynamic model of the global economy. The undertaking concluded by the publication of *Limits to Growth*. Dynamic models featured in that innovative work present how world economic growth is restricted by overexploitation of the environment and its resources.

Presently, systems dynamics are widely applied in medicine, chemistry, biology, physics, and mathematics, as well as social sciences – including economics. Evidence of the latter can be found in deterministic chaos models in human-made systems, models that explain the development of economic cycles, technology substitution processes, evolutionary mechanisms of coexistence of small and big enterprises, and economic growth mechanisms presented by Kwaśnicki [12-16].

Guo et al. [17] apply systems dynamics to regional planning and management of the natural environment. According to the authors, an important advantage of systems dynamics is the fact that individual components could be included in the general system structure, and subsequently subjected to a multifaceted analysis to check how the system functions. Knowledge related to the interactions between specific components, reflected in dynamic simulation models, allowed Guo et al. [17] to research multiple regional policy scenarios as well as their anticipated socioeconomic and environmental implications. Issues of environmental management according to the dynamic model are presented by other authors as well. Dynamic models for sustainable development presented by Michnowski [5] and Bajerowski [11] also are interesting and inspiring.

STELLA software, developed by IseeSystems, is an example of a contemporary application of the dynamic systems model creation method developed in the 1960s. A STELLA-supported development of the system model involves three levels. They are as follows:

- General model structure (Essential interdependencies between separated subsystems as well as key system interactions are explained),
- Flowchart (Quantitative interactions between variables that define a system's behavior are explained),
- Specific differential-subtraction equations (Behavior of the system is explained – the equation process is automatic).

The flowchart that is a visual depiction of system's structure and behavior is facilitated by these four main tools:

- Rectangle – cumulative variable defined as a level's name,
- Faucet – flow which is equivalent to a derivative,
- Circle – supplementary variable that may serve to define a model's parameters or ancillary interdependencies which define the system modeled,
- Arrows – tool that depicts interactions between specific variables of the model.

While working on the model, the user submits information about the system on the first two levels. Based on the information on model structure and the values of its parameters, differential equations are generated. The software applies assumptions concerning the predator-prey relationship to an evolving economy-environment system. The model created as a result is to answer the question concerning possibilities of sustainable development dynamics in the system.

Sustainable Development: Dynamic Perspective

Volterra's model adopted after Bajerowski [11] applies cumulative variables that constitute aggregated ecological and economic values. Flows are also marked on the flowchart (Fig. 1). On the one hand, they symbolize dynamic growth processes for these values, while on the other hand - their dynamic decrease progresses. Parameters of **a**, **b**, **c**, and **d** equations, which define a system's behavior, constitute ancillary variables. The arrows indicate points and directions of interactions between model components separated.

According to Volterra's model, interdependencies that occur in ecosystems and that define variable relationships in prey (x) and predator (y) populations are explained by the following pair of equations:

$$dx/dt = (a-by)x$$
$$dy/dt = (cx-d)y$$

Parameters of equations (a,b,c,d > 0) may be defined as follows:

a – Prey population growth index,
b – Predator effectiveness index – defines D-O section of encounters, ending in prey consumption,
c – Number of prey to number of predator offspring conversion index,
d – Predator extinction index after food runs out.

Bajerowski [11] claims that the model for the creation of aggregated ecological values (Vecol) and economic values (Vecon) may share the same assumptions, whereas ecological values may be substituted for the prey (x), and economic values for the predator (y). The author has studied the dynamics of such systems in a detailed way. Unfortunately, work quoted does not provide information as to how this model's parameters should be interpreted. Thus, we suggest the following interpretation:

a – Environmental potential reflecting the capacity for growth and reproduction of ecosystems,
b – Intensity of sourcing environmental resources by the economy,
c – Degree of economy's effectiveness in processing environmental resources,
d – Sensitivity of the economy to environmental deterioration, as well as to the exhaustion of its resources.

A dynamic process of changes in ecological values will be composed of flow (**ax**) directed toward that variable (Fig. 1). It describes an output potential of the environment and may be identified with the capacity of ecosystems exploited by the economy to reproduce. On the other hand, flow (**-byx**), exiting the cumulative, defines the power of an adverse impact of the economy on the environment. Economic values are powered by flow (**cxy**). This mathematical product points to a relationship between economic effectiveness and the pace of an economy's development at a given level for both system values: ecological and economic. Aggregated economic values are also sensitive to the shrinking of environmental resources and increasing resistance of the environment (visible through pollination, pollution, noise intensity, or harmful radiation intensity). Because of these reasons, environmental resources shrink at the pace of (**-dy**), marked by the flow exiting the cumulative variable discussed. This flowchart is depicted in Fig. 1.
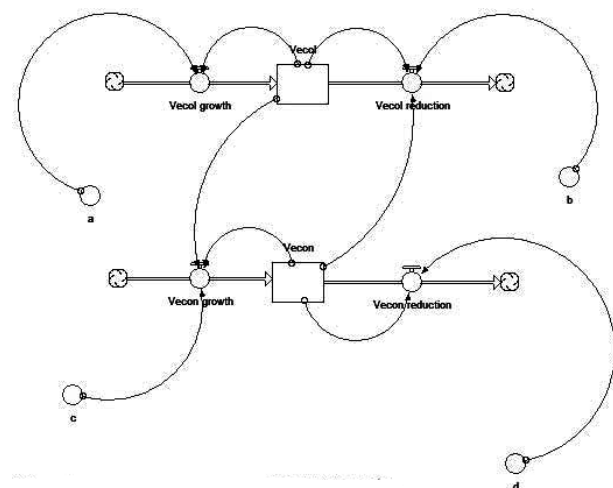

Fig. 1. STELLA flowchart for Vecol-Vecon system model.
Source: Own study.

It is assumed that the initial state of the system is a state where ecological values significantly exceed economic values. In other words, it is a situation where the environment is characterized by properties that are valuable to the human being in its initial penetration stage by humans. Economy is yet to develop, and the pace of its growth will be determined by an encountered system of initial values Vecol and Vecon, as well as the values of a, b, c, d parameters. According to these assumptions, the values are treated as follows: Vecol = 10 units, Vecon = 1 unit.

It is also assumed that the capacity of the environment to reproduce (parameter a) is higher than the intensity of sourcing its resources by the economy (parameter b). Moreover, it is assumed that economic effectiveness (parameter c) throughout the simulation period is relatively low, while the sensitivity level to environmental resistance and to the exhaustion of its resources (parameter d) remains moderate.

A specific notation of a model's equations in STELLA is as follows:

Vecol(t) = Vecol(t - dt) + (Vecol growth–Vecol reduction) · dt
INIT Vecol = 10
INFLOWS: Vecol growth= a · Vecol
OUTFLOWS: Vecol reduction = b · Vecon · Vecol

Vecon(t) = Vecon(t - dt) + (Vecon growth – Vecon reduction) · dt
INIT Vecon = 1
INFLOWS: Vecon growth = c · Vecol · Vecon
OUTFLOWS: Vecon reduction = d · Vecon

a = 0.04
b = 0.008
c = 0.01
d = 0.2

The model is launched for 100 years, assuming an interval time of dt=1 year, and a dynamic development process for both values is noted. The simulation indicates that assuming the above parameters, the cycle of changes Vecol-Vecon closes after approximately 80 years. Maximally aggregated ecological values reach 42 units, while economic values reach 22. Their changes in temporal function
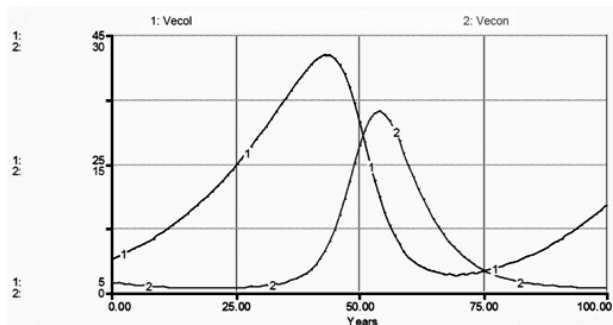
reveal characteristic developmental stages, typical of the predator-prey relationship (Fig. 2):

Phase I – Growth of ecological values, assuming the stagnation of economic values (up to year 35).

Phase II – Joint growth of both values (between year 35 and year 45).

Phase III – Growth of economic values accompanied by a reduction of ecological values (between year 45 and year 55).

Phase IV – Reduction of both values (after year 55).

Bajerowski [11] suggests studying the behavior of the system discussed in a two-dimensional phase space where aggregated ecological values appear on the axis of abscissae, while economic values appear on the axis of ordinates. Each state of the system is represented by each point in such a space. A chart depicts changes in the states of the system in time by way of a phase portrait.

The starting point for considerations concerning the phase portrait is located at the intersection of high ecological values and low economic values, which should represent truly historical values according to Bajerowski [11]. Points of intersections with the barriers of maximum and minimum values for both cumulative variables after they are connected with straight lines form the so-called cost-benefit borderlines (Fig. 3). It should be highlighted that exclusive initiatives located below the cost-benefit line Vecol are characterized by the desired growth of ecological values, while the growth of economic values is linked to just initiatives located to the right of the cost-benefit line Vecon [11]. It is easy to uniformly identify all developmental stages of the system in the above phase portrait. The field of eco-development, according to its traditional interpretation, is marked by trajectories running from point I to point III. It is worth noting that eco-development is a broader concept, identified with a set of initiatives aimed at not reducing ecological values. As Fig. 3 indicates, this may happen at the expense of economic values as well. Trajectories between points II and III mark the field of sus-
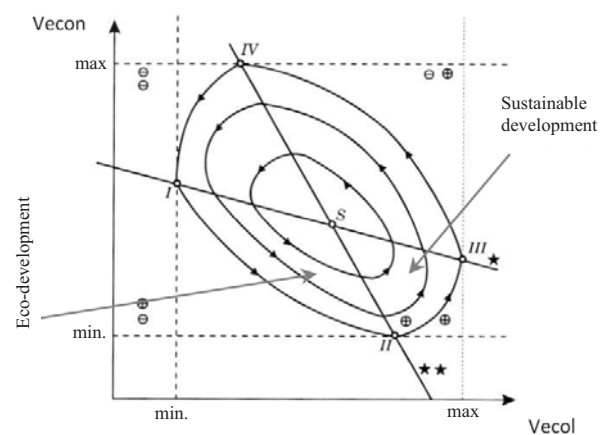

Fig. 2. The Vecol-Vecon system in temporal function. Simulation of the development system at fixed values of parameters a, b, c, d (simulation period = 100 years).
Source: Own study.

Fig. 3. Phase portrait of codependences between ecological and economic values Vecol-Vecon.
* – Line depicting the cost of ecological value benefits.
** – Line depicting the cost of economic value benefits.
Source: Bajerowski [11].

tainable development (joint growth of both values). Sustainable development is restricted by a wider range of conditions, thus it is represented by a significantly shorter trajectory. Phase III of a system's development illustrates the scenario where further growth of economic values takes place at the expense of the environment. According to Michnowski [5], the state in which an element of the system develops at the expense of its own surroundings or a different element in the system marks the state of external or internal loss of constructivity[1], implying a pathology that will principally result in regress if not overcome. This is a case with the developmental phase IV of the system – the economy linked to the deteriorated environment starts to experience stagnation, and subsequently collapses. This phase notes a marked reduction in both values simulated: ecological and economic ones.

Growth of Economic Savings and Effectiveness Versus Sustainable Development

According to Bajerowski [11], the only way to achieve higher economic results without deteriorating the environment is to adequately deform the image of the above cycle. Such deformation may be done in a twofold manner: by changing angles of cost-benefit borderlines or by moving the point of intersection of the lines, i.e. 'S', depicted in Fig. 3. Since the correct deformation of the cycle in areas essential from the point of view of sustainable development allows for expanding the desired area of joint growth of values Vecol and Vecon, it may be considered an objective of sustainable development.

Domański [18] believes that we are not in a position to increase production results just by way of increasing investment outlays for environmental conservation despite the indications of some historical data. The author's considerations imply that increasing only preventive outlays is not a sufficient measure in sustainable development processes. Most of all, a more and more thrifty economy and innovations that improve its effectiveness are required. Therefore, economic growth that consumes environmental resources should be accompanied by a gradual increase of parameter 'c' and a reduction of parameter 'b' in the modeled system. Hence, the next stage of the study involves the simulation of a scenario that assumes increasing economic savings and effectiveness, characteristic of wealthy countries whose environmentally-conscious elites protect the environment. It is assumed that over 100 years, economic effectiveness will increase five times (i.e. +4% p.a.), while the pace of exhausting environmental resources will drop twice (i.e. -0.5% p.a.) thanks to higher savings and dematerialization of economic processes.

Improved economic effectiveness and higher economic savings contribute to changes in the duration of particular phases of developmental cycles (Fig. 4):

Phase I – Growth of ecological values, assuming the stagnation of economic values (up to years 21).

Phase II – Joint growth of both values (between years 21 and 29).

Phase III – Growth of economic values accompanied by a decrease of ecological values (between years 29 and 38).

Phase IV – Reduction of both values (between years 38 and 53).

Thus, the system reaches the sustainable development stage as early as after 21 years. It is somewhat shorter but it is characterized by a higher level of possible economic values. As Fig. 4 indicates, a more effective and more efficient economy that consumes the same environmental resources is in a position to record much more significant growth. According to the simulation, this developmental stage is marked by maximum aggregated economic values exceeding values recorded by an economy that does not upgrade its quality and does not decrease the pressure it exerts on the environment by almost twofold.
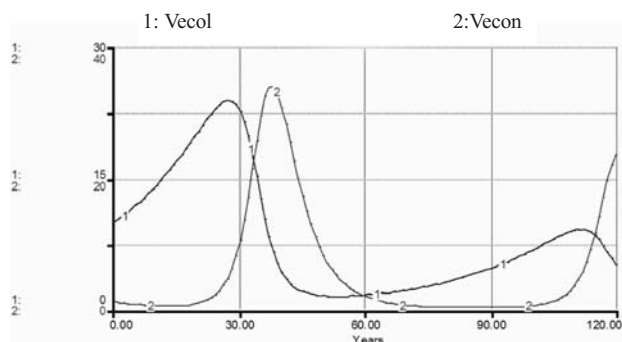

Fig. 4. Vecol-Vecon system in temporal function. Simulation of the development cycle at 4% economic effectiveness growth and 1% economic savings growth (simulation period = 100 years). Source: Own study.
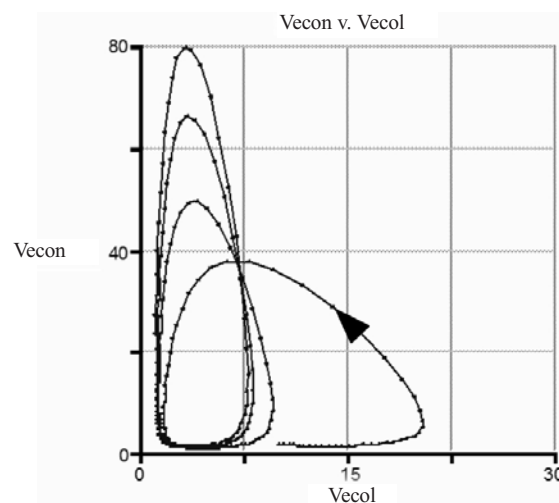

Fig. 5. Phase portrait of interdependencies between ecological and economic values Vecol-Vecon assuming increasing economic effectiveness and savings (simulation period = 300 years). Source: Own study.

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[1]According to Michnowski [21], a system's external constructivity is a behavior where implications of a system's life that are positive for the surroundings exceed negative implications. Internal constructivity is a state that results from implications that are positive for the system exceed its negative implications (it is also the condition for the process of a system's development).

In a longer-term perspective, the pace of growth for both economic savings and effectiveness gradually phases out. The following phase portrait illustrates how this system develops.

The figure depicts the development of new cycles. After a period of a joint decrease in aggregated values Vecol and Vecon, we can observe trajectories that are new quality-wise (Fig. 5), during which environmental resources Vecol gradually decrease. Despite this, an increasingly more efficient economy records higher and higher values on axis Vecon. Even though the pace of growth of economic effectiveness and savings phases out, the impact of changed parameters on the deformation of developmental cycles is clearly visible as subsequent trajectories change their shape from oval to slimmer and more elongated.

Implications of Economic Growth for Economies that Exert Increased Pressure on the Environment

Economies of poorly developed and developing countries are frequently characterized by the slow pace of absorption of innovations, and consequently – much lower effectiveness levels and a much slower pace of increasing the effectiveness. In such a case, high and frequently increasing intensity of sourcing and processing internal environmental resources is linked to a less effective (energy-wise and resource-wise) economy and the urge to make up for economic drawbacks (relative to the contemporary world) at any cost. Such a model of managing resources may also be accompanied by a gradually diminishing capacity of the deteriorated environment to reproduce ecosystems. Such a scenario is explained in the following way: the initial state of the system is respectively the state in which ecological values significantly exceed economic values (Vecol = 10, Vecon = 1), whereas within the first 100 years of the simulation, parameter 'a' decreases three times (i.e. -0.60% p.a.), parameter 'b' increases four times (i.e. +2.75% p.a.), parameter 'c' increases by 2.5 times (i.e. +1.50% p.a.), whereas parameter "d" remains constant throughout the entire simulation period, equaling 0.200.

A development marked by low economic effectiveness and resources being utilized in a more and more intensive way, while affecting an environment's capacity for regeneration, follows this scenario (Fig. 6):

Phase I – Growth of ecological values assuming the stagnation of economic values (up to year 27).

Phase II – Joint growth of both values (between years 27 and 34).

Phase III – Growth of economic values accompanied by a reduction of ecological values (between years 34 and 48).

Phase IV – Reduction of both values (between years 48 and 77).

In this case, simultaneous growth of ecological and economic values is relatively short. An ineffective economy reaches its peak value of as low as 2.30 units in its final stage (18 times lower than Vecon of an economy that

increases its effectiveness and savings). Only further development of the system at the expense of ecological values allows recording maximum economic values of 8 units (it is worth mentioning that under simulations an efficient economy records such values as early as at the stage of sustainable development). A reduction of both these values according to such a management model is significantly more disadvantageous – in the following cycle, economic values disclose very low numbers (Fig. 7).

Even if we are to assume that adverse phenomena are phased out in the future, subsequent cycles that are created as a result of developing such an ineffective and increasingly more parasitic economy will be of a cyclical nature. Both ecological outcomes as well as economic implications will be marked by increasingly lower values. As long as qualitative changes in the way increasingly more scarce resources are managed do not take place, such an economy will be heading for a downfall.
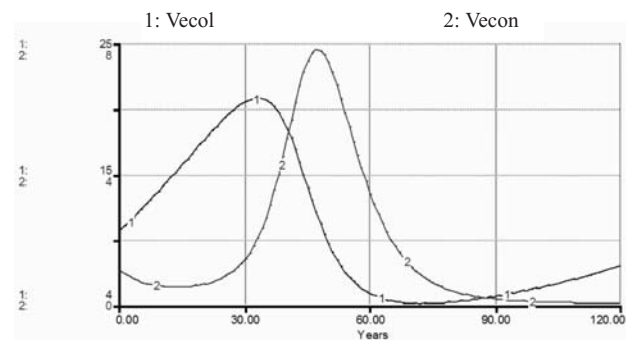

Fig. 6. Vecol-Vecon system in temporal function. Simulation of the development cycle at 2.75% growth of the intensity of sourcing environmental resources, 1.50% growth of economic effectiveness, and 0.6% drop of the capacity of the environment to reproduce ecosystems.
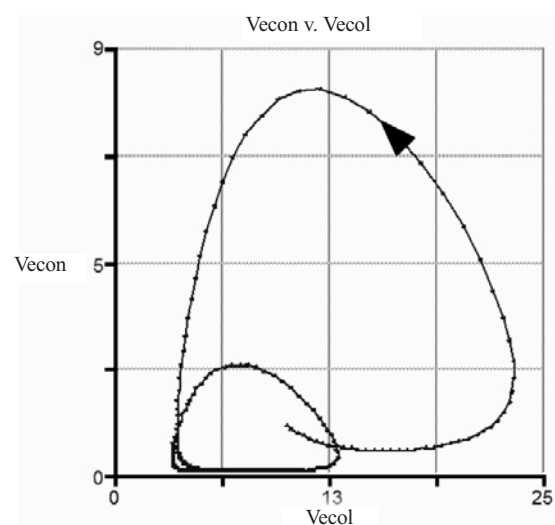Source: Own study.

Fig. 7. Phase portrait of interdependencies between ecological and economic values Vecol-Vecon assuming low economic effectiveness, growth of intensity of sourcing resources, and a reduced capacity of the environment to reproduce ecosystems (simulation period = 300 years).
Source: Own study.

Summary and Conclusions

Volterra's model, which has inspired this study, is undoubtedly a considerably far-fetched simplification of reality. Still, the application of STELLA has made it possible to perform a simulation of systems dynamics for systems marked by variable parameters that define both the pace of ecosystems' reproduction as well as the intensity of sourcing environmental resources by the economy and its effectiveness. By the same, the models have become much more reflective of reality as joint growth of the economy and ecology is no longer marked by uniform oscillations. Dynamic changes of the parameters are accompanied by developmental cycles that are either phased out or intensify (an outcome of qualitative changes in the economy and the environment). It is also possible to analyze their implications for further development of the system.

Despite being theoretical in nature, the model developed in STELLA may present a valuable practical aspect. By monitoring the development of the system in longer time horizons, a model's parameters may be mapped out by adjusting them to a system's dynamics. Thus, a calibrated model could serve not only to describe an existing situation, but also serve as a forecasting tool to define subsequent developmental stages of the system as well as their qualitative characteristics. Suggestions put forward by Bajerowski [11] concerning deformation of the developmental cycle understood as the essence and goal of sustainable development would also gain practical meaning.

It is worth citing after Weiner [19] and posing a basic question about the conditions of lasting coexistence between the predator and the prey (in our case, the economy and the environment). The response is strictly linked to Fig. 3, which depicts a phase portrait of interdependencies between both system components of the system. In phase space, the state in which $dx/dt = 0$ and simultaneously $dy/dt = 0$ occurs only at point 'S'. It lies at the intersection of isoclinic lines, i.e. cost-benefit borderlines. Hence, assuming data parameters of a system (a, b, c, d), aggregated economic and ecological values that ensure equilibrium are coordinates of that point. A simple conversion of equations indicates that they are as follows: Vecol = d/c, Vecon = a/b.

The point marked by an intersection of isoclinic lines is at equilibrium. Any other combination of values Vecol and Vecon represents a point at one of the trajectories which close around the equilibrium point. Outside the equilibrium point, the system starts oscillating. Ecological and economic equilibrium values are inversely proportional to the values of parameters 'c' and 'b'. In other words, the higher the intensity of sourcing scarce environmental resources by the economy and the higher the effectiveness of such initiatives, the faster the equilibrium point is reached and at lower values of Vecol and Vecon.

The dependence of the economy on the environment and its resources is difficult to debate. Economic growth, anticipated and continuously monitored internationally by politicians, investors, analysts, and economists, takes place (regardless of economic effectiveness and savings) at the expense of the environment [2, 3]. This is why it has been assigned the role of the prey in our system. Systems theory implies that such a scenario must have its consequences. According to the model presented, economic growth linked to the environment is cyclical. Environmental awareness and behavior in developed countries facilitates achieving higher economic results, assuming the same levels of environmental resource output. However, this does not change the scenario whose end result is regression both of the environment and of the economy that develops at the expense of the environment. It is also characteristic that both growing economic savings and effectiveness, and outlays incurred on compensatory and suppletive initiatives that offset deficiencies and enrich environmental potential, do not reverse the trend.

The following question arises: how should the environment be managed in the context of the above conclusions?

Jan Tinbergen, an economist and the 1969 Nobel Laureate, voiced a very mature opinion at the time [9]. According to him, two things are endless: the number of generations that we should feel responsible for, and our own inventiveness. The former provides a challenge to us: to feed and ensure access to an unlimited stream of earth's natural resources not only for the present but for all future generations. The latter: our own inventiveness can create concepts and ideas that will contribute to meeting the above challenge.

Al Gore [20], another Nobel Laureate, suggests 'balanced investments' while claiming that environmental issues as well as other ecological factors may be factored into business strategies to guarantee optimum return on investment while keeping ecological balance intact.

According to the systems model, providing a solution to the issue of managing the environment is simple. It is put forward by Michnowski [5] while introducing the concept of 'sustainable development resonance.' To specify, an economic system could sustain its life oscillations on an ongoing basis as a result of developing new and appropriate interactions with its surroundings – the environment. It would be based mainly on positive feedback. According to the concept, energy and matter that have been collected, processed, and are no longer needed in the economy and are released into the environment, become – in the system's perspective – demoted. However, an economy that discloses an appropriately high level of its development is probably in a position to cause the demoted energy and matter to become a life factor of a different component of the system in the future. In order for this to happen, the future system should be formed so that it complies with the needs of the development of the environment and its component ecosystems, as energy and matter released to the environment may – depending on their form – trigger two types of distinct consequences. They may restore equilibrium to the surroundings and improve the quality of its life, or they may destabilize and destroy it. Such behavior on the part of the system whose elements enrich one another and trigger shared development are termed by Michnowski [5] as 'sustainable development resonance.' According to him, a prescription for lasting growth is universal in this case, i.e. if

the surroundings (the environment) undergo fast and adverse changes (and this is the case once the system completes the sustainable development phase), in order to survive, systems created by us should sensibly manage resources that have already been collected. Besides unprecedented instances of economic adjustment, it is necessary, however, to act on the environment so that its life may be sustained and simultaneously a positive homeostatic reaction – one which sustains our life – may be sourced from the environment.

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