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APPLICATIONS OF INFORMATICS IN ENVIRONMENT ENGINEERING AND MEDICINE

Editors:

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This book consist of the papers describing the applications of informatics in environment and health engineering and protection. Problems presented in the papers concern quality management of the surface waters and the atmosphere, application of the mathematical modeling in environmental engineering, and development of computer systems in health and environmental protection. In several papers results of the research projects financed by the Polish Ministry of Science and Information Society Technologies are presented.

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CHAPTER 2

Mathematical Modeling in Environment Engineering

THE MODEL OF SIMPLE ECONOMY WITH EMISSION CONSTRAINT

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*Our objective is to conduct simulations with economic –environmental model.
We list the important and causal relationships among the levels and trace the
feedback loop structures. In describing an economic and environmental model
we focus on the relations among income, consumption, emission, and damage.
This paper yields insight into maximization of welfare. Next, we present the
simulation runs of the model, conducted with the help of existing system
dynamics modeling tools.*

Keywords: Economic model, environmental systems, optimization,
simulation.

1.   Introduction

This paper examines the possible impact of economic development and
maximization of welfare on environmental quality. The paper consists of 5 chapters
including introduction. We present opinions on the influence of economic
development on environment, with the stress on the Club of Rome ideas in the
chapter 2. In chapter 3 we describe relations in our model, and we present the results
of our simulations and conclusion in chapters 4 and 5.

2.   The different viewpoints on growth and environment

In the debate over growth and environment, we have two views: optimistic
and pessimistic. Proponents of optimistic view argue that continued economic
growth will produce less polluted, and more resource rich world (Ophardt, 1997).
Beckermann (1999) claims that growth is beneficial due to supporting social
improvement. Stiglitz (1996) suggests that the elasticity of substitution between two
inputs: capital and resources is sufficiently large with new technologies. Lovejoy
(1996) imply that technology can change substitution over time so there is less
scarcity. Mikesell (1995) emphasizes the lack of evidence that growth leads to lower
productivity.

Some other researchers indicate that for a specific kinds of environmental
problems the relation between income and the level of environmental pressure

shows an inverted U curve (Arrow, at al. 1995; de Bruyn and Heintz, 1999; Dinda, 2001; Grossman and Krueger, 1995). The conclusion of those studies can be criticized on several grounds. Results obtained from cross-section data cannot be translated to future time-series for specific countries. Moreover, empirical studies only focus on particular aspects of environmental pressure not related to the carrying capacity natural resilience of ecosystems.

Overall, optimists view two things: (1) the elasticity of substitution between an essential resource and capital is greater than 1, and (2) technology will increase the productivity of resources faster than their exhaustion. The empirical literature provides a mixed and partial picture. While some studies yield substitution elasticities greater than unity (a necessary condition for economic growth models to generate sustainable paths) for metal: steel, copper and aluminium (Brown and Field, 1979), others suggest that for scarce materials like beryllium elasticity is close to zero (Deadman and Turner, 1988).

Pessimists claim that sustainability recognizes that without intervention the global environment will not be able to provide a reasonable standard of living (Helm, 2000). Malthus (cited by Solow (2000)), was the first who pointed out the possibility of growing relative scarcity of natural resources. The authors of 'The Limits to Growth' Report continue to argue that economic growth must be lowered along with other changes (Meadows, 1972). The analyses in the report did draw public awareness to the need for saving and conserving the environment and natural resources (Hayami, 1997). Daly (1996) suggested that renewable resources should be used in amount no greater than the rate of regeneration.

Club of Rome Report emphasised the examples of exponential growth: world population has been growing exponentially since the beginning of industrial revolution. In 1991 annual growth rate was estimated as 1.7%, which means a doubling time of 40 years. Also world production, relative to the base of 1963 year show clear exponential increase, as well. The concentration of carbon dioxide in the atmosphere has risen from 290 parts per million in the last century to over 350 parts per million and will continue on its exponential growth path. According to Intergovernmental Panel on Climate Change (IPCC), atmospheric CO_2 concentrations by 2100 will be in the range of 650 to 970 ppm. The increased atmospheric concentrations of CO_2 and other greenhouse gases (GHG) trap more of the earth's heat, causing temperatures to rise. As a result, it is predicted that the global average surface temperature can rise between 1.4 and 5.8 degrees Celsius between 1990 and 2100, an unprecedented rate of increase. These in turn are responsible for melting ice, rising sea levels, and a greater number of more destructive storms.

The 'Limits to growth' study made a valuable contribution to our knowledge on sustainable development in bringing the implications of unbounded growth at a time when the environmental capacity was often thought to be unlimited. The

nature of the policy prescription of the World3 arises from the way the resources sectors have been modelled. The stocks of these resources have outflow, but not inflow, which causes collapse, since the outflow continue with production.

Acharay and Saeed (1996) modified the "Limits" model first to accommodate the model variety. The modified model generated the behaviour similar to the original model under realistic assumptions, although it contained latent structure for arriving at robust equilibrium. When run for longer time, Model "Limits to growth" spell doom, even when their policy recommendation are applied. Hayes (1993) claimed that policies, which seem to ensure sustainable future could only postpone collapse until middle of next century.

The resources ecosystem of the earth is a relatively small subsystem within the universe and it derives its energy from sun. Most resource policies currently we use fall into reactive category. Implementation of reactive policies requires powerful exogenous intervention. Corrective policies aimed at improving market mechanisms attempt to ensure efficient use of resources. We must emphasize that market mechanism assure only intra-temporal efficiency of resources and they cannot address the issue of inter-temporal equity. Market economy claims that restoring resources for futures makes sense only when the expected resource' future price is increasing at a rate that is at least equal the market rate of interest. Therefore, market mechanisms always favour present use of resources over future one (Saelid, 1996) Understanding the fact that markets may fail to allocate resources properly also favour public intervention to slow down and stretch out the exploitation of resources pool. The model, however, rules out any inputs into global resource system. One could say that the fixed stocks take into account the ultimate available resources, including sun energy, but the time frame of such stocks would be extremely long.

3.   The analysis of main relations

First, we consider macroeconomic relations with capital, income, consumption, and savings (Solow, 2000). Capital is accumulated by the amount of investment and decreased by depreciation in a specified time unit, like one year. We assume all production comes about as a function of capital and labour (equation 1). The consumption per capita is minimum from consumption per capita and substantial level of consumption. Subtracting consumption from income yield investments. Saving can be changed into investments goods like raw materials, thereby increasing capital stock.

Our goal is to maximize welfare consumption per labour force (1)

$$\max \sum_{t=2001}^{t=2029} c_p \frac{1}{(1+r)^t} \tag{1}$$

where c_p is consumption per labor forces, *t-time, r-discount rate*.

Labor force is given by equation 2, where. g is increase of labor force.

$$L = L_0 \ (1 + gL) \tag{2}$$

We assume the stock of capital is increased by new investments and decreased by depreciation. The stock of capital is given by equation (3):

$$K_{t+1} = K_t \ (1 - \delta) + I_t \tag{3}$$

where δ is depreciation rate, K_{t+1} is capital in time $t+1$, K_t is capital in time t.

Production is given by Cobb-Douglas formula with technological progress (equation 4).

$$Y_t = e^{\gamma t} \ K_t^{\alpha} L_t^{1-\alpha} \tag{4}$$

where δ is depreciation rate, K_t is capital in time $t+1$, L_t is labour force.

For the data from Polish economy (1990 prices) we calculate coefficient of Cobb-Douglas function: $\alpha = 0,2830$, and coefficient of technological progress: $\gamma = 0,044$.

The output is either consumed or invested in the new capital or spend for emission reduction. Due to environmental damage from emission, the part of output available for consumption is lower production process (equation 5)

$$Y_t = C_t + I_t + ER + ED \tag{5}$$

From the data of Polish economy we set environmental damages as equal 10% of total output. Next, consumption per worker is given by equation 6:

$$c_t = \frac{C_t}{L_t} \tag{6}$$

Number of working force is calculated by optimization of consumption per capita. Some relations described above are presented on the Figure 1.

Finally, let us assume that production and consumption activities generate as by-products industrial emissions, represented here by carbon dioxide. The increased amount of atmospheric carbon dioxide has a considerable influence on the growth paths, since the economy heavily depends on the use of fossil fuels that causes an emission of carbon dioxide and eventually environmental damage: global warming.
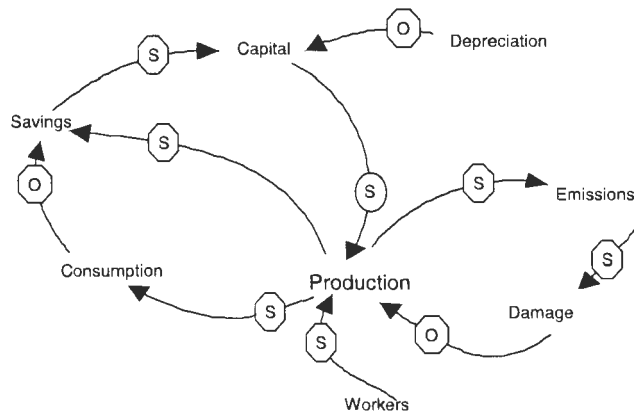
Figure 1. Diagram with reinforcing loop between capital and income and consumption, and balancing loop between Non-renewable resources and income. *S*- change in the same direction and *O*- change in the opposite direction.

4.   The results of simulation

We distinguish two scenarios in our simulation: (1) without emission constraint, and (2) with emission constraint. The results of first simulation show that in the coming decades, we can expect increase in capital, industrial production and in labor force. After 30 years of our simulation, the labor is increasing with exogenously given growth rate from the value 17000 in 2001 to the value of 23000 in 2020, i.e. for 27% (figure 2). At the outset production increases for 18%. In the first scenario emission of pollutants are increasing from 30300 in initial year to the level 35822 in 2020 year (i.e. for about 17%). The cost of emission reduction is zero since abatement is not applied here. As a result, production is completely allocated to investments in capital and consumption. From the other side, the increase of emissions causes environmental degradation. Environmental damages increase from initial value 3023 to 3582 in the last period of our simulation (figure 3). The sum of discounted, optimal consumption per worker equals 42,65. Total consumption increases from 50000 in 2001 to the level 61000 in year 2020. Investments equals depreciation-about 6700, due to condition that depreciated capital must be replaced by new one. Coefficient of consumption per worker decrease from the level of 3,07 w 2001 year to 2,93 in 2020, as labor force increases and total consumption decreases.

In the second scenario emission of pollutants are increasing from the 30230 in 2001 to 33000 in 2011 and are on that level as emission constraint is introduced to the model (Figure 4). Damages are proportional to the emission increase from the level 3023 and are stable on the level 3300 in 2011. Emission constraint condition causes

necessity of emission reduction and therefore emission reduction cost increases. Emission reduction is zero until 2011 year, when it equals 188, then it increases to the level of 2822 until the end of our simulation (figure 5). Therefore, cost of emission reduction increase from 0in 2011 to the level 5645 in 2020.

The sum of discounted, optimal consumption per worker equals is almost the same 42,10. Consumption increases from 50000 in 2001 o to 5593 in 2011 and stays on that level until th end of simulation: 2020. Investments equals depreciation -around 6700, due to constraint in our model. Production increases from the level 60461 in 2001, to 71645. Labor force increases from 16487 in 2001 to 22206 in 2020, similar to the first scenario (figure 4). The rate of output increase is lower than in first scenario, due to higher costs of abating pollution. After 30 years of our simulation emissions and environmental damage are increased for about 20% (figure 4 and 5).

Coefficient of consumption per worker decreases from the level 3,07 in 2001 to 2,52 in 2020, as labor force exogenously increases. Consumption per labor force is increasing by 34% (figure 6). The coefficient of consumption to production increases from the value of 0,84 to 0,9 in 2011, and after it decreases to the value of 0,75 (figure 7).

5.   Conclusion

The results of simulation support view that growth may lead to the exhaustion of natural resources and deterioration in the environment. Economic growth leads to increase of pollution, together with global warming. Higher emissions may decrease output and lead consequently to a decrease in consumption. We can circumvent such development by limitation the inefficient use of fossil-fuels, and common application of renewable sources of energy. Moreover, comprehensive revision of existing policies in rational consumption is necessary. Therefore, emphasis on sufficiency, equity and quality of life rather than quantity of output is necessary.

The renewable energy can protect us from global warming. To accomplish this goal, we have to follow Brown (2001), who shows how to change the economy. In that new economy, wind farms replace coal mines, hydrogen-powered fuel cells replace internal combustion engines and cities are designed for people, not for cars.
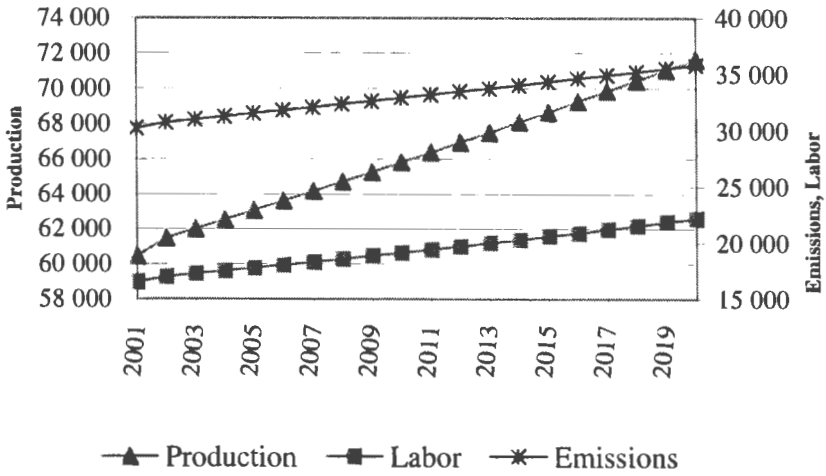
Figure 2. Results of our simulation in the first scenario (no emission constraint)-emissions, labor force and output.
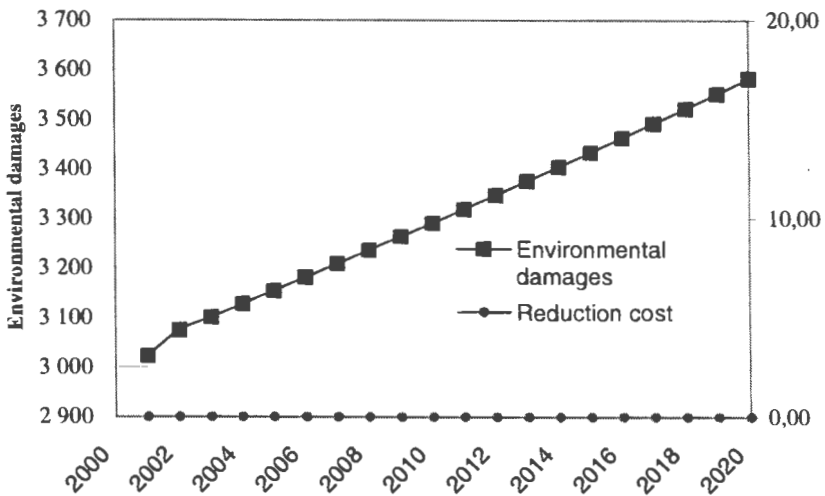

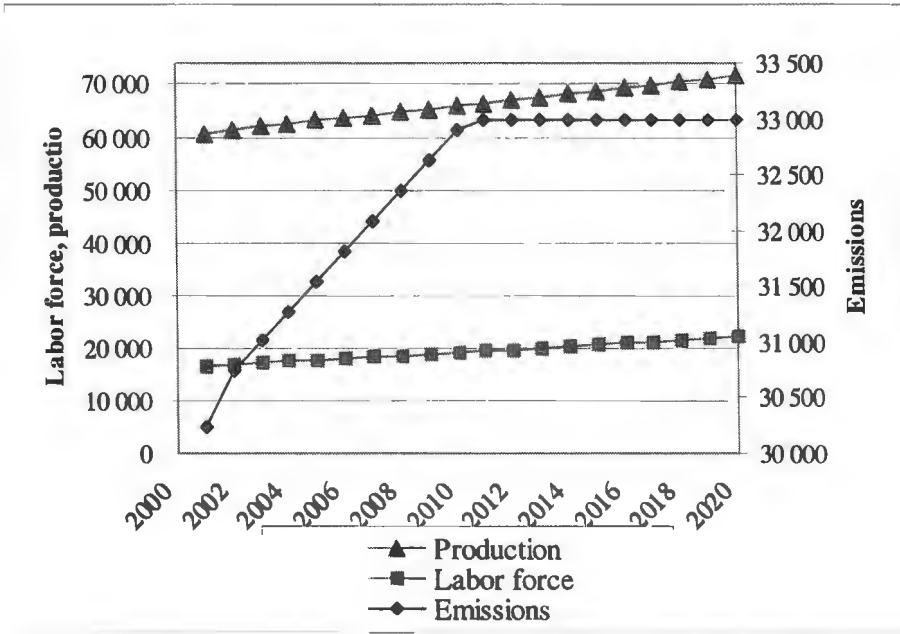**Figure 3.** Simulation results-second scenario. Environmental damages and emissions of pollutants.

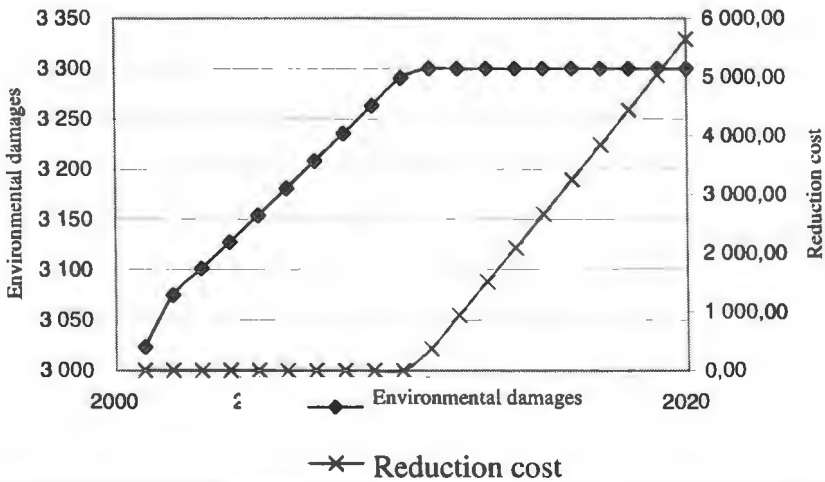**Figure 4.** Simulation results-second scenario. Production, labor force and emissions.

Figure 5. Simulation results-second scenario. Environmental damages and reduction cost.
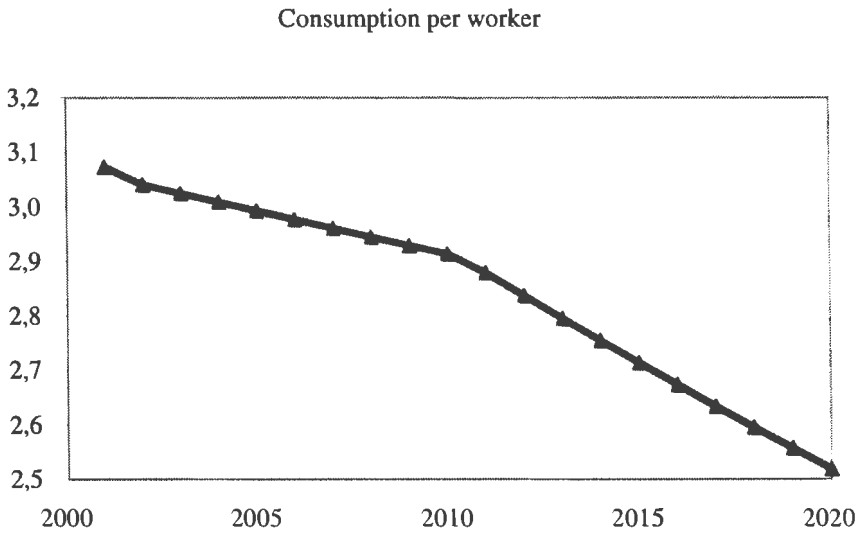
Consumption per worker

Figure 6. Simulation results-second scenario. Environmental damages and reduction cost.
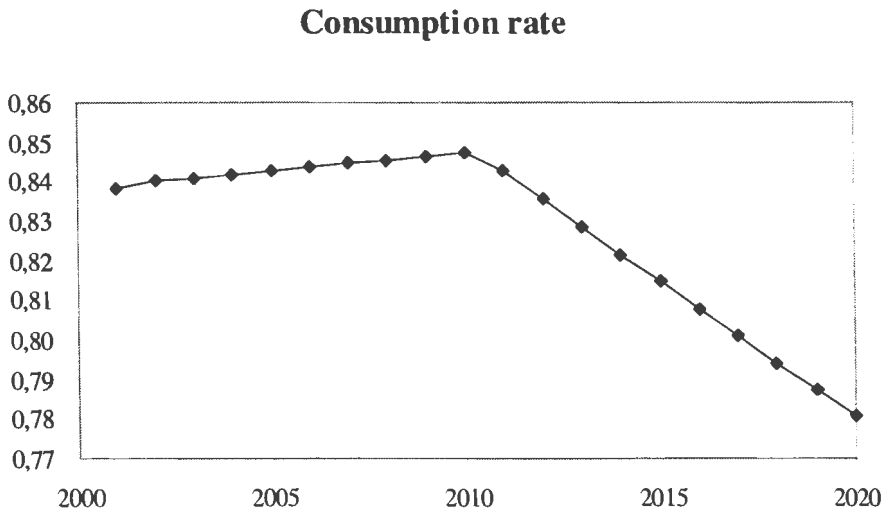
Consumption rate

Figure 7. Simulation results-second scenario. Rate of consumption to production

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APPLICATIONS OF INFORMATICS IN ENVIRONMENT ENGINEERING AND MEDICINE

The purpose of the present publication is to popularize applications of informatics in environment and health engineering and protection. Runned papers are thematically chosen from the works presented during the conference *Multiaccessible Computer Systems* (*Komputerowe Systemy Wielodostępne*) that has been organized by the Systems Research Institute and University of Technology and Agriculture of Bydgoszcz for several years in Ciechocinek. Problems described in the papers concern quality management of the surface waters and the atmosphere, application of the mathematical modelling in environmental engineering, and development of computer systems in health and environmental protection. In several papers results of the research projects financed by the Polish Ministry of Science and Information Society Technologies are presented.