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SUSTAINABLE DEVELOPMENT ANALYSIS[1]

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The purpose of the research programme Citizenship and ecomodernization in the information society – the futures approach – is to study the social and ecological dimensions of emerging information society. Particularly we aim at assessing social impacts of new informational structures that are impinged on citizens. We also focus on analyzing the ways application of information technology influences on targets and realization of sustainable development. The study programme comprises of ten individual research project organized around above sketched themes.

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ABSTRACT

A comprehensive logical framework of the global ethos of sustainable development is outlined in the paper. The ecologically sustainable development as one of three institutional processes of the ethos is on the focus of the analysis. The ecological sustainability is thoroughly elaborated in mathematical terms enabling to gain new insight of the subject necessary for any disciplined empirical analysis and monitoring the course of the real life situation.

Key words: sustainable development, global ethos, dematerialization, immaterialization, welfare productivity, structural shift.

1. INTRODUCTION TO CONCEPTUALIZATION OF SUSTAINABLE DEVELOPMENT

Sustainable development had its first roots as an internationally relevant issue already in the first UN Environmental Conference in Stockholm in 1972 (Federation of Engineers 1972). It became firmly formulated by the UN World Commission on Environment and Development in 1987 in the so-called Brundtland’s report ’Our Common Future’ (WCED 1987). And finally the global ethos of sustainable development became agreed on and confirmed by the world governments in Rio in 1992 in the UN World Conference on Environment and Development (United Nations’ Agenda 21 1993). Enormous number of researchers, institutions, citizens and citizen groups have intellectually contributed for the ethos and better understanding the issue of development ever since Rachel Carlson’s book Silent Spring (Carlson 1962) and the Club of Rome reports, i.e. The Limits to Growth (Meadows et al. 1972) and the others (FICOR 1997).

Sustainable Development is formulated (ref. WCED) generally as an ethos that ”humanity has the ability to ensure that it meets the needs of the present (especially of the poor) without compromising the ability of the future generations to meet their own needs”. This ethos is rational and possible under the cosmic enduring conditions of the earth, which are outside the human control e.g. the amount and characteristics of solar radiation and its magnetic activity. A drive for ecologically sustainable development as part of the ethos becomes necessary for a reason that the humankind is able to deteriorate the earthly conditions of a dignified human life by exploiting Nature in an unwise technical way. The ecological sustainability is an expression of a human intention to keep the earth living and capable to co-evolve with enduring human existence.

When the sustainability issue is looked merely from the human point of view where Nature is merely seen as an environment and a stockpile of resources of human affairs the term sustainable development is used. When instead ‘Nature’s affair’, i.e. Nature as a living whole is taken as the relevant point of departure, the term biological diversity or biodiversity is regarded as more adequate by the scientists (Wilson et al 1997).

The two departures lead to prioritize and study different things but both aspirations have in common the ethos of sustaining the material base of life on earth and protect it as an inheritance and privileged rights of the future generations.

The discourse on sustainable development embraces, however, more than just the ecological sustainability or biodiversity. To meet the needs of the present is an important part of the ethos of sustainable development. To the developing countries it means fighting poverty and eradicating it in a reasonable time. Increasing poverty and diminishing solidarity among citizens is, however, an acute problem in many industrialized countries, too. Poverty is also an equally important cause factor to the ecological unsustainability as is striving for excessive material affluence. This is the double vicious circle to be overcome with sustainable development.

To eradicate poverty calls for changes of social institutions maintaining unjust human conditions, i.e. it needs social development in terms of justice, equality and solidarity. Just and equal democratic social development is a constitutional process of sustainable development.

The third constitutional process is a liberal and creative cultural process, which generates the bases of the scientific knowledge, technology, arts and humanistic values necessary for the ethos of sustainable development.

Sustainable development as a whole appears as an interaction of the three processes, as depicted in figure 1, and not as an end state of human existence (Jokinen et al. 1998). In another paper I have argued that sustainable development is the post-modern idea of progress (Malaska 1997b).

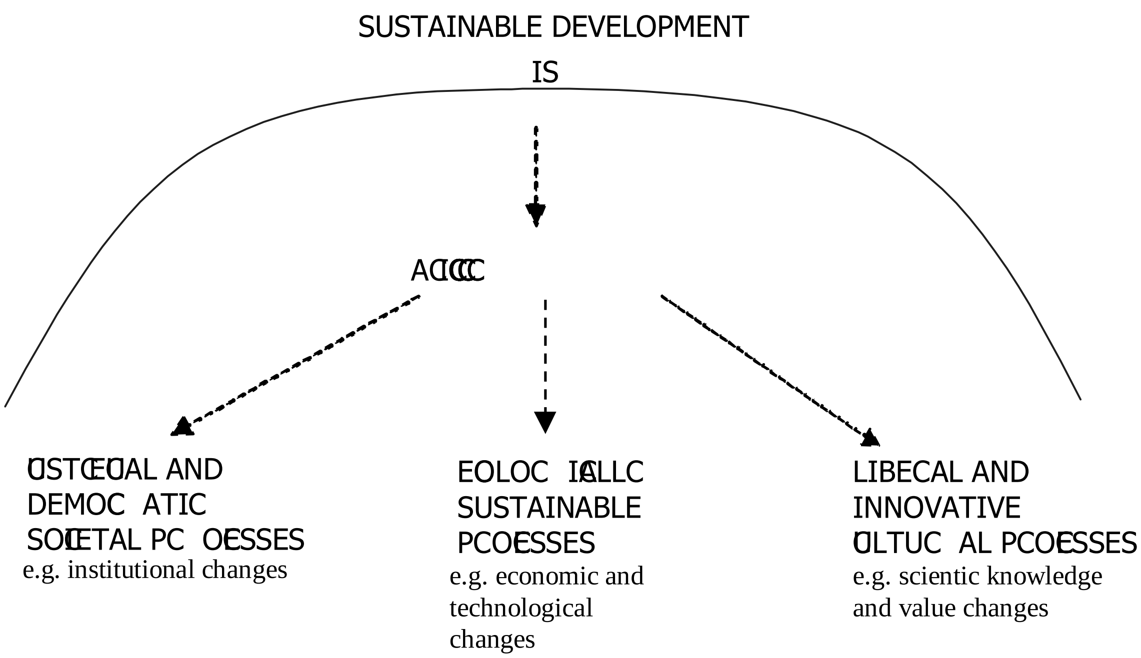

Figure 1. The Whole and parts of the process of sustainable development.

PRINCIPIA ETHICA OF SUSTAINABLE DEVELOPMENT

A. To fight poverty and unequal economic standing, especially in the developing countries

B. To stop the depletion of nature and destruction of the environment

C. To secure for future generations the same opportunities for well-being and freedom of choice as we enjoy

D. Sustainable development should be socially just and equal, ecologically and economically sustainable, politically and culturally free and innovative

Table 1. The Ethos of sustainable development

Table 1. gives a summary of the ethos of sustainable development. The study is focused next on the operationalizing of the ecologically sustainable development.

2. THE ECOLOGICALLY SUSTAINABLE DEVELOPMENT

2.1. Operationalization of sustainability and the total environmental stress with material flow

The ecological sustainability is related to the total environmental stress of Nature and her processes (TES) provided by humankind. It is hypothesized that a nonincreasing or decreasing TES is a necessary (but not alone sufficient) condition of sustainability. Environmental stress is caused by humans first by exploiting natural resources from Nature for production and consumption and secondly by rejecting and discarding wastes and pollution back to Nature thus depleting her space and function. Level of the TES is thought to be accounted with the material flow (MF) from Nature through the technosystem back to Nature (Malaska 1971, 1987, 1997a). The material throughput (MF) is chosen here as an operationalization and adequate measure for the TES. In mathematical forms the arguments of sustainability are

(1) $TES \cong MF$ (operationalization of TES with MF)

(2) $\dot{MF} < 0$ (sustainability condition)

Where $\dot{MF}$ means the rate of change of the material flow.

The formula (2) defines mathematically decreasing material flow through the technosystem as a necessary condition of sustainability. If this condition is not attained the human system is not regarded as ecologically sustainable. The question of how the material throughput (MF) can be measured is omitted here.

The ecologically sustainable development will be analysed only qualitatively in the paper. The logic behind the analysis is the logic of identities or tautologies; i.e. the basic formulas and the results are true of their logical nature just because they are tautologies without any empirical or other verification.

2.2. Master equations for sustainability analysis

From the basic hypothesis TES = MF in eq. (1) four identities master equations are formulated for the analysis. The first master equation relates the ecological sustainability (MF) to the economic production (eq. 3 and appendix 1). The second identity is for consumption and welfare related with sustainability (eq. 5 and appendix 2). The third identity relates the sustainability to employment and automation (eq. 8 and appendix 3), and the fourth to structural shift of the economy (eq. 10 and appendix 4). With each identity important conditions of sustainability is revealed and concepts for empirical and analytical studies specified.

2.2.1. Dematerialization of production

With three measurable indexes, i.e. population (POP), production volume per capita (GDP/POP), and material intensity of production (MF/GDP), the master equation of production for sustainability can be defined as and in eq. (3).

(3) $$MF \equiv POP \times \frac{GDP}{POP} | \times \frac{MF}{GDP} |$$

The master equation states that the total environmental stress (MF) is related in a multiplicative form to the population, production volume per capita, and the material intensity of the economic production. It means that the larger the human population, and the higher the level of the economic production per capita is, the stronger the environmental stress is going to be, and further the more intensive materially the economy is the stronger environmental stress it affects.

The sustainability condition in (2) demands that the rate of (3) should be decreasing. We may try to estimate to what extend the present day economies are meeting this condition?

A population growth from 5 to 10 or 12 billion people in twenty years is expected before any levelling off, i.e. the first factor of eq. (3) on the right hand side is increasing for sure. The growth of the second factor by 2-5 %/a is an economic objective of any governments.

The only factor, which could be decreasing on the right of eq. (3), is the last one, i.e. the material intensity of GDP. This process of decreasing is called dematerialization. From it a necessary condition of dematerialization of production can be derived.

$$(4) \qquad \overset{\bullet}{\left.\frac{MF}{GDP}\right|} < 0 \qquad \text{(dematerialization)}$$

The dot above is for the rate of change of the material intensity. The condition expressed by eq. (4) is that of a dematerialization process of production. The quantitative value of the rate of dematerialization required for maintaining present day situation is about 4-7 %/a. A factor four decrease of the material intensity should be needed (Weizsäcker et al. 1995) in about 30-40 years time in order to keep eq. (3) in balance.

2.2.2. Immaterialization of consumption and welfare productivity

The material intensity of GDP can be elaborated further and as a result the consumption side be related with sustainability. Referring to many recent empirical studies on the subject (Van Dieren 1995, Max-Neef 1995, Stockhammer et al. 1997) it is assumed that an index of the real welfare, different and better one than the GDP, can be defined and measured quantitatively. Let's have WF to stand for the real welfare index. The consumption and welfare identity is given in (5).

$$(5) \qquad \frac{MF}{GDP} \equiv \left.\frac{MF}{WF}\right| \times \left.\frac{WF}{GDP}\right|$$

where on the left-hand side there is the material intensity of GDP from eq. (3); the first term on the right is the material intensity of consumption /welfare, and the second factor is the welfare productivity of GDP. It indicates how much real welfare is gained in consumption per each GDP unit produced.

The welfare productivity $\left.\frac{MF}{GDP}\right|$ is a new concept omitted so far from the economic discourse. It is emerging quite naturally and unavoidably in the sustainability analysis.

Immaterialization is a process of decrease of the material intensity of consumption, i.e.

$$(6) \qquad \overset{\bullet}{\left.\frac{MF}{WF}\right|} < 0 \qquad \text{(immateralization)}$$

The condition (6) means improving eco-efficiency.

The GDP index is an international measure not only of the volume of the economic production but also of the standard of living and the development level of a country.

There is, however, a growing amount of substantial critique against its use as a welfare measure and for economic policies. There is as yet no other international standard for a real welfare index albeit numerous alternative measures have been studied as refereed earlier.

From these studies it appears that about by 1980 the real welfare indexes and the GDP index were in a moderate confirmity, where as thereafter their message on real development starts to deviate more and more from each other and became contradictory (Luukkanen, et al. 1998).

A new concept for welfare policy is needed in order to complement the conventional economic growth concept in the welfare discourse. With the first factor of eq. (5) the welfare productivity increase is formulated as a necessary condition of sustainable development, i.e.

$$(7) \qquad \dot{\frac{WF}{GDP}}| > 0 \qquad \text{(welfare productivity increase)}$$

Instead of the continuous economic growth in GDP terms the sustainability commands a growth of the welfare productivity. Appendix 2 summarizes the results presented.

2.2.3. Employment and automation dilemma

From the first sight the relation of the ecological sustainability is opaque and obscure to employment; the effect of automation on the contrary appears supportive to sustainability, because of a possible improvement in the use of natural resources. That aspect is, however, already taken into account by the dematerialization process of production (see appendix 1). The identity relation of the employment and automation to the total environmental stress in (8) reveals different aspects of automation and employment.

$$(8) \qquad MF \equiv POP \times \frac{EMP}{POP}| \times \frac{MF}{EMP}|$$

When the growth of the population in (8) is an unavoidable fact for a long time to come, and maintaining the employment level of population as high as possible is a policy priority, the only factor in eq. (8) which can have a decreasing effect on the environmental stress is the last factor $\frac{MF}{EMP}|$ on the right hand side. The material flow per employed worker in production should become smaller in order to keep sustainability. However, the real economic development runs to the opposite direction: the quantity of (MF/EMP) is bound to increase with automation. The very process of automation means that a smaller number of workers will manage and handle larger and larger volumes of material flow because of more and more efficient production systems and machines, i.e. the last factor is in fact also increasing.

(9) $$\dot{\frac{MF}{EMP}}| > 0 \qquad \text{(automation condition)}$$

With the objectives of employment (to maintain high level of employment) and objectives of technology development (to advance automation) it seems unavoidable that environment deterioration will continue as a price for a material standard of living. This is a vital dilemma between the economic development and sustainability with no solution as far as one is bound to a non-diversifiable economic system. In the eq. (8) there is no room for diversification to show up. In search of a solution it is necessary to look after a possible structural shift of the economy from the dominating mode of production to a new more diversified mode with essentially different sustainability characteristics from those of the old mode, e.g. a shift from the industrial economy with tangible material produce to a service economy of intangible information services.

2.2.4. Structural shift of the economy

The role of a structural shift of the economic system, as for example from the industrial economy to a post-modern service economy, is analysed in appendix 4 and in eq. (10). The starting point is the controversial factor of the material intensity of employment in eq. (8). It can be partitioned into a sum of two terms eq. (10). The first one presents the old, dominating mode of production and the second one the new and penetrating mode of production.

(10) $$\frac{MF}{EMP} = \frac{MFo}{EMPo} \times Wo + \frac{MFn}{EMPn}(1 - Wo)$$

where the weight factor Wo represents the degree of penetration measured as the ratio of the labour force.

(11) $$Wo = \frac{LFo}{LF}$$

and LF stands for the labour force.

Now, the dilemma in (8) and can be solved, and a decreasing trend of the left-hand side is possible to reach even with advancing automation. The necessary condition is that there is a big enough diversification of economy through the shift of labour force from the old production mode (e.g. industry) to the new mode (e.g. services). Industry itself will be reorganized and forced more and more into service business, it becomes more service-intensive and then it is going to loose its dominant role to service mode as the determinant of societal rationality.

The structural shift, which enables to counterbalance the negative effect of an expected trend of automation on sustainability, is

(12) $$\frac{\Delta W_o}{W_o} = -\left|\frac{1}{\frac{MF_o}{EMP_o} - \frac{MF_o}{EMP_o}}\right| \times \Delta\left|\frac{MF_o}{EMP_o}\right|$$

balancing structural shift — a coefficient of balancing — expected rate of automation

In appendix 4 some more results of the diversification are presented.

3. DISCUSSION

Theoretical analysis disclosed several key concepts of the ecologically sustainable development, which have been discussed in the literature and studies recently. This analysis brought them together and elaborated further and built first time a coherent logical framework, which connects the sustainability concepts with economic concepts of employment, automation, diversification of economy, welfare productivity and dematerialization of production. The theoretical results can be operationalized further with a methodological approach known as the general decomposition calculus (Luukkanen et al. 1998, Sun 1997, Sun-Malaska 1998) and new kinds of empirical studies can be undertaken accordingly on sustainability and economic growth.

Sustainability and Production Identity

The production identity relates the total environmental stress (TES) measured with the material flow (MF) through the technosystem to the economic production activity (GDP) and population (POP). The concept of dematerialization process of production is derived from this identity.

$$MF \equiv POP \times \frac{GDP}{POP} \Big| \times \frac{MF}{GDP} \Big|$$

- MF — environmental stress
- POP — population
- $\frac{GDP}{POP}$ — production volume per capita
- $\frac{MF}{GDP}$ — material intensity of production of GDP

Dematerialization of production

is a process of decreasing material intensity of production. Mathematically it is expressed by

$$\dot{\overline{\frac{MF}{GDP}}} \Big| < 0 \qquad \text{(dematerialization process)}$$

where the dot above means a change of the material intensity over a time unit; the equation states that for sustainability it is to be negative meaning a decreasing intensity.

(MF = material flow, POP = population, GDP = gross domestic product)

Sustainability and Consumption and Welfare Identity

The consumption and welfare identity relates the material consumption and welfare to the sustainability discourse through the material intensity (MF/GDP). The concepts of eco-efficiency and welfare productivity of GDP are revealed.

$$\frac{MF}{GDP} \equiv \frac{MF}{WF} \times \frac{WF}{GDP}$$

$\frac{WF}{GDP}$: welfare productivity of GDP

$\frac{MF}{GDP}$: material intensity of production

$\frac{MF}{WF}$: material intensity of consumption

Immaterialization of consumption

is defined as the decreasing material intensity of consumption and improving eco-efficiency.

$$\overset{\bullet}{\frac{MF}{WF}} < 0 \qquad \text{(immaterialization process)}$$

Welfare productivity of GDP

is the second term on the right hand side. It is one of the ultimate measures of economic development. Instead of the GDP growth the welfare productivity growth should be on the base of sustainable economic policies, i.e.

$$\overset{\bullet}{\frac{WF}{GDP}} > 0 \qquad \text{(welfare productivity process)}$$

(MF = material flow, WF = welfare index, GDP = gross domestic product)

Sustainability and Employment Identity

The employment identity relates the total environmental stress measured with the material flow to the employment level of population and the material flow per worker employed in production. The concept of automation process is defined.

$$MF \equiv POP \times \left(\frac{EMP}{POP}\right) \times \left(\frac{MF}{EMP}\right)$$

- MF: environmental stress
- POP: population
- $\frac{EMP}{POP}$: employment level of population
- $\frac{MF}{EMP}$: material throughput per worker employed in production

(dilemma)

In this identity maintaining the employment level constant or increasing is an aimed policy of any government, population is growing and due to automation in industry also the last factor is increasing. This is a sign of sustainability dilemma.

Automation

of production systems means or it leads to an increase of the material flow through the system with less number of workers needed to handle it. The advance of automation is thus governed by the condition of the (MF/EMP) factor as

$$\overset{\bullet}{\left(\frac{MF}{EMP}\right)} > 0 \qquad \text{(automation process)}$$

(MF = material flow, POP = population, EMP = number of employed people)

Appendix 4

Sustainability and Structural Shift Identity

A structural shift of the economy means that a new more diversified model of production and consumption emerges and takes dominance of the economy from the prevailing, more monolithic production and consumption mode. The present development from the industrial economy to service economy is good demonstration of a structural shift. The employment identity of sustainability in appendix 3 is modified to take into account the structural shift situation.

The last factor of appendix 3 is modified for a diversified economy, giving the structural shift equation.

$$\frac{MF}{EMP} = \underbrace{\frac{MF_o}{EMP_o}}_{\text{dominating mode}} x\, W_o + \underbrace{\frac{MF_n}{EMP_n}}_{\text{penetrating mode}} x\, (1 - W_o)$$

where the shift weights

$$W_o = \frac{LF_o}{LF} \quad \text{and} \quad (1 - W_o) = \frac{LF_n}{LF}$$

are the labour force ratios of the new (subscript n) and old (subscript o) modes of production and consumption. It is also necessary that

$$\frac{MF_n}{EMP_n} << \frac{MF_o}{EMP_o} \qquad \text{(characteristic condition of shift)}$$

A structural shift of ΔW_o enables to counter balance the increase of the environmental stress caused by the advance of automation in the old production mode. This was an unsolved dilemma in the production mode economy of appendix 3. The equation of the diversified structural shift is given as follows

$$\frac{\Delta W_o}{W_o} = - \frac{\Delta \dfrac{MF_o}{EMP_o}}{\dfrac{MF_o}{EMP_o} - \dfrac{MF_n}{EMP_m}} \qquad \text{(balancing condition)}$$

(MF = material flow, EMP = number of employed people, LF = total labour force, W = labour force ratio, o = subscript for the old mode of production, n = subscript for the new mode of production)

Δ stands for a change of the quantity. The greater the rate of automation is the greater structural shift is necessary in order to maintain the sustainability condition. And the bigger the characteristic difference in the dominator is between the old and new dominating modes the easier it is to obtain the balance.

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ABSTRACT

Sustainable development is introduced in the article as an ethos and post-modern idea of progress, i.e. an ideal for betterment of humankind. A sine qua non for the ideal is that ecological sustainability is made a quality standard for human economic, social and material welfare. Necessary conditions of ecological sustainability are derived. The theory is based on mathematical elaboration of the self-evident identities between the total environmental stress (TES) and the basic indicators of economic, technological and social development. Explanatory power of the theory is demonstrated with new important concepts and formula.

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