Resource management stability: outlook on issues and analysis

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Abstract Based on the multi-criteria approach the models for life cycle chain have been tested. The undertaken optimization provides the tools for sustainability development of the material flow, which one represents rational resource management within its economic, ecological and social criteria through the innovative market instruments towards combining private and public interests.

1 Introduction

1.1 Rational resource management

The current world economic crisis has induced the strategic challenge for the further development of market based instruments. The innovative area for this belongs to the modern environmental efforts within the competitive markets to provide sustainable production and consumption. The further business rehabilitation will increase the international trade with the inevitable growing of the involved resources. The resource subject is the huge area in every economy, and it is extreme important to find the right priorities between the possible management options. The efforts currently address how to improve resource efficiency and to reduce the negative environmental and social impacts of resource extraction, processing, use and disposal, while securing adequate supplies of materials to sustain economic activities and responsibilities related to the future developments. And so, the research into rational resource management needs to be equally broad bred in its scope to overcome this global international challenge.

1.2 Life cycle approach

Numerous attempts have been undertaken towards the noted above problem, among which the Life Cycle conception provides wide prospects to follow promising sustainability paradigm. The micro-level material flow analysis (MFA) at this way provides a detailed information for specific decision processes at business. [1]. An other micro-level application is a life cycle inventory as a step in life cycle assessment (LCA), which is a widespread tool in product-related environmental policies [2]. LCA conception for the material flow chain is here under consideration in conjunction with the market forces. MFA information from business level material flow accounts or mass balances is used to monitor developments in resource productivity, environmental and social performance [3]. The life cycle model is the starting point for the undertaken research on the rational resource management. Here are “standard” elements like the life cycle stages: “mining, M”, “production, P”, “consumption, C”, “treatment, T”, and transaction activities in the form of markets "resources, R", "goods, G", "wastes, W". Also the public "damage, N" is taken into account.

1.3 Life cycle models

Relating to the market model, our basic approach is followed by the specification of preferences and production sets [4]. An equilibrium in the market is a price and an allocation such that for each demand and supply, correspondently, the preference-maximizing and the profit-maximizing with the balance condition are provided. The private agents in the life cycle chain have profit and utility functions, and the material flow is designed in balance of demand and supply driving forces. By known optimization tool the cost functions and the utility functions for the noted preferences and profits could be introduced as well[1]:

$$i = 1 \div I,\ QM^i = <\pi^R, V^i> - CM^i(V^i) \qquad (1)$$

$$j = 1 \div J,\ QP^j = <\pi^G, V^j> - CP^j(V^j) - <\pi^R, U^j> \qquad (2)$$

$$k = 1 \div K,\ QC^k = CC^k(U^k) - <\pi^G, U^k> - <\pi^W, V^k> \qquad (3)$$

$$l = 1 \div L,\ QT^l = <\pi^W, U^l> - CT^l(U^l) \qquad (4)$$

1 Here is <a, b> - inner vector product

Here are CM, CP, CT[2], and CC - costs (mining, production, treatment), and utility (consumption), π - specific price vector, and material equations:

$$U^j = m^j V^j, \quad V^k = w^k U^k \tag{5}$$

with m, w - specific rates for resource consumption, and waste production. Every market in the life cycle chain is provided by the agents of two types: supply, with private criteria QS(X), and demand, with private criteria QD(Y). By the targets {QS(X) → max} & {QD(Y) → max}, the multi-criteria model at the every stage is introduced. It could be solved under "classical" conditions[3] like this: Q(π, X, Y) → max, where Q is a linear normalized combination of supply and demand criteria. The multi-criteria technique, e.g. [5], provides the equilibrium point (π, X, Y), which belongs to the Pareto set.

2 Issues

2.1 Private and public interests

Based on LCA, for every market with supply (X) and demand (Y), the negative release could be accounted (N(X, Y)). Its impact is represented by a damage power, modeled by a risk function (R). The multi-criteria approach provides the issue, combining private and public interests: {QS(X) → max} & {QD(Y) → max} & {R(X, Y) → min}. Here are the private targets of supply and demand activities for profit and utility maximization, while the public component is under desirable minimum for the damage. This triple optimization meets the equilibrium of private and public interests in the economic equivalence after the damage term:

- there is a function in the form of cost, reflecting supply risk, RS;
- there is a function in the form of utility, reflecting demand risk, RD.

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2 There is known the economists` conviction that efficient waste processing and recycling is best achieved by setting appropriate price incentives, but the other approach, with the treatment utility is also possible.

3 In accordance to [4, 6] it means absence of externalities, convexity, and continuity of preferences, and the convexity and closeness of the consumption set.

2.2 Supply and demand responsibility

Extended producer responsibility conception is known, which embodies the notion that production agents should share responsibility for the externalities` of the product. The model being under discussion illustrates this issue in the following way, e.g. at the supply side: $QS(X) = <\pi, X> - CS(X) - RS$, having the equilibrium $(\pi(r), X(r), Y(r))$, instead of the equilibrium (π, X, Y), for $QS(X) = <\pi,X> - CS(X)$. The difference $\Delta QS = QS(X(r)) - QS(X)$, the similar is at the demand side, provides information about the efficiency of the measures for responsibility.

2.3 Speculation challenge

The non-stability problem [6] at the market is that some sellers claim that their costs are high in order to increase the price, while some buyers prefer to claim that their utilities are low in order to reduce prices, etc. The model being under discussion illustrates this issue in the following way. Given $QS(X) = <\pi, X> – CS(X)$, and $QD(Y) = CD(Y) - <\pi, Y>$, where CS, CD are “truthful” cost and utility, and the equilibrium is (π, X, Y). At the bargain instead above said, there is used $CS(X) \rightarrow CS(X) + \Delta CS(X)$, and the similar for demand, with the equilibrium $(\pi(\Delta), X(\Delta), Y(\Delta))$. If, e.g., $\Delta QS = QS(X(\Delta)) - QS(X) > 0$, then there is no presumption that the supply players will tell the truth at the demand-supply game.

2.4 Stability option

The allocation mechanism is a communication system in which participants exchange messages [4]. To identify the optimal mechanism one supposes several rational rules for it: (a) “direct mechanism” with reporting private information from agents; (b) “incentive compatible” if it is a dominant strategy[4] for each participant to report his private information truthfully; (c) “participation constraint” if there is no agent should be made worse off by participating in the mechanism. The fundamental “negative” result is known [6] about a standard exchange economy, where there is no Pareto-optimal (a, b, c)-mechanism. So, operating with the private information precludes the efficiency. The model being under discussion has a power to investigate the noted issue. During the supply-demand bargain the following multi-criteria issue is under design: $\{QS = <\pi, X> - CS(X) - \Delta CS(X) - RS$

4 “dominant strategy” - if it is an agent`s optimal choice, irrespective of what other agents do.

$\rightarrow \max\} \ \& \ \{QD = CD(Y) - \langle \pi, Y \rangle - \Delta CD(Y) - RD \rightarrow \max\}$ and the equilibrium is $(\pi(\Delta,r), X(\Delta,r), Y(\Delta,r))$. The real interests are provided by $QS(\Delta,r) = \langle \pi(\Delta,r), X(\Delta,r) \rangle - CS(X(\Delta,r)) - RS(X(\Delta,r), Y(\Delta,r))$ and $QD(\Delta,r) = CD(Y(\Delta,r)) - \langle \pi(\Delta,r), Y(\Delta,r) \rangle - RD(X(\Delta,r), Y(\Delta,r))$. The differences $QS(\Delta,r) - QS$ and $QD(\Delta,r) - QD$ provide a technique to investigate the stability issue at the presence of a risk term.

3 Analysis

3.1 Private and public interests analysis

As to issue #2.1, it needs to note that in the scalarization of general multi-criteria analysis there is the task of scaling for criteria having different numeraires[5]. It is seen that Pareto-optimum is invariant to the constant numeraires. The real units have a practical sense, e.g., for societal costs. In particular, there is known the problem of sustainability indicators[6]. Given, the “sustainable development” is the state of economy with compromise at the appropriate sense between economic, environmental, social and institutional objectives[7.] The decoupling indicators claim to a ratio between the macro-level overall environmental impact related to resource use and the overall economic indicators[8.] By the above introduced approach, the decoupling indicators have to be calculated as a relative measure between the current state and the equilibrium:

- the product life cycle provides three markets for resources, goods and wastes,
- the every market has supply and demand interests (private) as well as environmental and social interests (public),
- at least two groups of criteria will control the market: economic (by supply and demand) with environmental and social (by damage power),

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5 e.g., is a basic standard by which values are measured (an abstract unit of account).

6 Decoupling indicators, basket-of-products indicators, waste management indicators - framework, methodology, data basis and updating procedures European Commission, Joint Research Centre, 2010

7 3rd European Commission Life Cycle Workshop (2007) provided an integrated focus on the “...balancing environmental, economic and social objectives...”

8 The concept of decoupling (W. Bosmans, EC, DG ENV) is intended to reduce the negative environmental impacts of resource use in a growing economy, and, as a consequence, to improve resource efficiency, in particular, the indicators (have to) to measure progress (towards sustainability) in efficiency and productivity in the use of natural resources, including energy.

and, the desired indicator system (decoupling, basket of product, or waste management) has to be introduced as the measure for the discrepancy of the necessary equilibrium conditions at the appropriate market (with standard normalization technique). The material flows and the price messages, being experimentally observed, provide enough basic information to calculate these indicators.

3.2 Supply and demand responsibility analysis

In the part of issue #2.2, the introduced approach looks fruitful at forthcoming implementation of wide version for producer responsibility principle in market based instruments as well as one can find here the tools for marketing of the public sound goods with supporting for advanced technologies instead of the "usual" decreasing the production[9]. Under assumed RS = εG, the difference ΔQS can be calculated in the form (by ε-order):

$$\Delta QS = X\{(\sum \partial G / \partial^2 CP)/(\sum 1/\partial^2 CP - \sum 1/\partial^2 CC)\} - G \qquad (6)$$

and, to be negative, (6) needs for some limitation of the growing responsibility[10]. More deeply undertaken investigation can introduce the consumer responsibility as well, and, while the previous one goes to decrease production activity, the last one via consumer stimulation for public sound goods provides production growth.

3.3 Speculation challenge analysis

After issue #2.3 one can see that the standard assumptions on concavity provide stimulus to apply the bargain speculation. Let`s take ΔCS(X) in the form εF, with growing F, so we have the assessment ΔQS = QS(X(Δ)) - QS(X) (by ε-order):

$$\Delta QS = X\{(\sum \partial F / \partial^2 CS)/(\sum 1/\partial^2 CS - \sum 1/\partial^2 CD)\} > 0 \qquad (7)$$

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9 Known "western" approach to oppress pollution with direct taxes against "eastern" option to support public goods by market forces.

10 With standard assumptions on concavity, e.g.,

$\partial CM(V) > 0,\ \partial^2 CM(V) > 0,\ \partial CP(V) > 0,\ \partial^2 CP(V) > 0,\ \partial CC(U) > 0,\ \partial^2 CC(U) < 0,$

$\partial CT(U) > 0,\ \partial^2 CT(U) > 0$; Here is used dim V = dim U = 1, for notations` simplicity, as well as here is used sign "∂" for a derivative (first order) or ∂^2 for a recurring derivative (second order) with the context-appropriate argument and the inequality interpretation, etc.

Starting from (7), the equilibrium price moves up after suppliers` "efforts" (S), and backwards after demanders` ones (D). In the both cases, the equilibrium volume goes down. There is seen some "positive" phenomenon of bargain speculation, e.g., damage decreasing (there is some price stabilization too, if S&D speculations go simultaneously). Regular and controlled results at this way are seen from the presence of the risk term (R) in the optimization task[11]. The last one is close connected with the specifics of the damage assessment. In particular, damage dependence in the life cycle chain by "supply" and "demand" volumes needs to be suited rationally, e.g., in accordance with a hypothesis for weighted summation of pollutions having the similar impacts. The other option is modeling the damage power in the form, as it was used earlier:

$$R = \sum RM + \sum RP + \sum RC + \sum RT \qquad (8)$$

3.4 Stability option analysis

In issue #2.4 the problem of equilibrium attainment has been addressed. There is known the idea that attaining equilibrium would involve a process by which market groped a way toward equilibrium price with the help of a "fictitious auctioneer". The examination of the modified gradient process (simultaneously varied material flow and prices at the presence of a risk term, e.g., (8)) leads to the conclusion that this process moves in the direction of the competitive equilibrium under the appropriate convergence conditions. Having the convergence properties of the modified gradient process for all markets at the life cycle chain, we can take the total allocation mechanism in the form[12]:

$$\delta V = \partial QS - \partial \Delta CS, \quad \delta U = \partial QD - \partial \Delta CD, \quad \delta \pi = \sum U - \sum V \qquad (9)$$

Due the mechanism (9) we can see some regular options for stabilization. The approach could be used to stabilize markets or auctions via "negative" feedback loop, at least at the level of "ε" (infinitesimal stabilization). In particular, let`s suppose in the introduced allocation mechanism for the resource stage, the risk term is growing by the resource price argument. Then, based on (1), one can minimize the speculative effect at the resource bargain, because ΔQM goes down:

$$\partial QM^i = \pi^R - \partial CM^i(V^i) - \partial RM^i(\pi, V^i) \qquad (10)$$

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11 In particular, there is interest in sign of $\partial^2 R$ >, <, = 0

12 Here is δ – derivative by "time" argument

$$\partial_{\varepsilon} QM^{i} |_0 = < \partial_{\varepsilon} \pi, \quad V^{i} - \partial_{\pi R} RM^{i}(\pi, V^{i}) >|_0 \qquad (11)$$

In deed, the above introduced approach (10, 11) is a little bit yet, because the equilibrium point is not known[13]. But, based on the appropriate gradient process (9), there could be attained some adaptive convergence to find the equilibrium.

4 Conclusions

The introduced models in adds to the undertaken case-studies[14] provide the confidence on practical prospects of the multi-criteria approach for life cycle developments. As it can be resumed, the rational resource management is seen via the optimization task with the multiple objectives: economic, environmental, and social. By identifying the key nodes in a causal network relating to material flows in resource management the introduced approach at least can:

- help in getting to grips with cross-thematic issues;
- assist in constructing more focused sustainability indicator sets;
- facilitate measures for stability, etc.

5 References

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13 Here is "|o" sign for the term calculated at the equilibrium point.

14 E.g., among the others: Voronov A. A multi-criteria approach for system and process design relating to waste management, in Geotechnical and environmental aspects of waste disposal sites, Sarsby & Felton (eds.) Taylor & Francis Group, London (2007); Voronov A. Resource management: outlook from NW Russia on issues and analysis, in Sixth Finnish-Russian environmental seminar (2008), <www.environment.fi/SYKE/seminars>