Aggregation of Environmental Data

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Abstract**—**The paper deals with environmental data measuring and related problems. The main problem is undefined relation. On one hand, there are subjects which produce harmful substances or activities; on the other hand there are harmed subjects. The first subjects are known, those are the owners of the activities which cause damage while the other subjects are unknown. This leads to the fact that damage quantification and their value are practically not exactly measurable. It is, however, possible to work with assumptions and solve partial problems. The mathematical view sees it as defining scalar representatives of the comparative indicators such as prices. The paper draws attention to the fact that the literature often presents incorrect conception, e.g. the price level is defined by basic price index. The base has an assigned unit level. The indexes in general are, however, indicators of changes.

Key words**—**Aggregate indicator, damage measurability, environmental data, macro level

I. INTRODUCTION

THE undesirable activities are brought by the modern civilization. These activities might unfavourably influence the life on this planet and are connected to long-lasting and repeated creating of outputs on a large scale. It is not only the impacts of air and water pollution and landscape destruction but these activities are also related to damaging the natural resources such as tropical rain forest cutting which harms the circulation of water in all its forms.

The undesirable phenomena and activities are a result of human activities. They are usually not connected to the needs of people as such but to stockpiling of human-created tools such as money, financial capital, company profits and increasing of diversification among people.

To simplify, let us consider pollution caused by harmful substances emissions and let us answer such questions as:

What is pollution?
Who pollutes?
What is the rate of pollution bearing capacity?
What are the results of pollution?
What influence does the pollution have on the environment?
How much does it cost and what profits does it bring?

Modern technologies require processes which are connected to harmful substances emissions or other undesirable phenomena.

For decision tasks of these issues is necessary to create indicators. These indicators will have different levels of aggregation.

II. SELECTED ENVIRONMENTAL DATA AND ATTRIBUTES OF INDICATORS

The data usually have three basic attributes:

- factual aspect of the indicator defining its meaning
- place or places the indicator relates to
- time of period which is described by the indicator

The meaning of the indicator must be defined clearly and unambiguously. It needs to reflect the particular occurrence or process complexly. It may not be in conflict with other indicators and cannot duplicate any other indicator.

The particular occurrence or process might be divided into parts while it is necessary that the parts are delimited clearly, must be disjunctive and their unification has to cover the full occurrence or process.

The place is defined by the area which the indicator is related to. This area might be e.g. a country, region as well as geographical area etc.

Time or Period

The indicator describes an entity which belongs to a certain time or time period. We mark the time stamp with a symbol, e.g. "t" or "s". The symbols defining time are usually attached to the indicator in the form of index.

A time period is a time interval $<s, t)$ determined by two time stamps s and t where $s<t$. The time s is the beginning of the period while time t is the end. The length of a period is the difference between the end and the beginning, i.e. t-s.

Sometimes the interval $<t-1,t)$ is called also as t. The fact whether we talk about time or interval is visible from the circumstances. Interval $<t,t+dt)$ with a very short length of dt is call infinitesimal interval and dt is a infinitesimal magnitude.

A. Undesirable Phenomena and Activities

Let us use a simple example of heat production to demonstrate the complexness of the undesirable activity quantification.

It can be seen that heat production is connected to activities which depend on: necessary amount of heat, burnt substance, utilizing waste from burning, waste disposal, cost of equipment for burning, operational cost, cost related to damages from burning, cost for reducing damages, price of heat and yield from operations, price of emission damages, sustainability of activity, repeatability, etc.

As for damages, it is necessary to follow the sequences of causes to quantifiable impacts, e.g. dispersion of selected pollutants and the impact on a particular group according to the selected character of damage (via dose – response).

Besides the obvious damages there are activities which produce future danger.

B. *Some Economics Solutions in Terms of Environmental Economics*

The economics of environment is a part of economics science which attempts to define the value of damaged environment, the cost to remove pollution and preserve nature and - more generally - puts emphasis on the need of an efficient policy to protect the environment. Certain production cost stand outside the production subject, therefore they are an externality; especially damages on environment are often cost that the producer does not have to cover. Negative externalities should be included to the economic calculations of all economic subjects; the cost of the nature should become a part of the cost of the producer. This leads to two questions:

- Is it possible to determine the cost of nature in all its form in a monetary form?
- How to internalize the cost of the nature to the internal cost of a production subject?

Utilizing Ownership Rights

Ronald Coase, a supporter of neoliberalism, suggests using the principle of ownership rights (for natural resources). There are two options:

- The producer disrupting or polluting the environment has the right to this behaviour (e.g. ownership) and it depends on the aggrieved to preventively compensate this potential polluter for the loss of profit by not using this right. E.g. a neighbour who is annoyed by noise from a workshop buys silence from the workshop owner and compensates him for not being able to make money.
- The other solution is derived from the assumption that the right for resource ownership (e.g. right for silence) is in the hands of the aggrieved. Therefore, the victims will be compensated for loss by the producer disrupting or polluting the environment.

In both cases, it is possible to express the cost monetarily.

This system cannot be used for the global pollution (acid rains, greenhouse effect, damaging of the ozone layer etc.) where it is difficult to find the victims as they are often not aware of being the victims (the problem of information availability and transparency on the market of polluting the environment), with difficult evaluation of the cost (how to investigate and put a price tag on increased risk of more frequent occurrence of cancer in regards to other risk factors?), and it is difficult to find the polluters (every person breathes out CO_2) and also the future generations are not able to negotiate about the compensation[1],[12].

Using Taxes - the Polluter Pays

This principle has been taken from the theoreticians of the welfare economics (A. C. Pigou, A. Marshall) who were the first to analyze externalities. The intervention of the state is mild in this case: the state will prescribe a tax to the polluter in the value of the damage and the polluter is thus motivated to invest into harmless material in order to avoid the tax. The government might also offer subsidies to those who invest to eliminate pollution. It is also difficult to determine the valued of the damages caused by global or long-term pollution.

Approval to Pollute

The state or a specialized agency sets a desirable level of acceptable pollution and provides a licence for the right to damage the environment within an intensity limited by the level which should be reached. Some of these rights might be sold on the market: those who pollute less might sell not used rights to those who pollute more, therefore, the purchase price becomes an internal cost item for the buyer. This system is relatively effective for local pollution but meets obstacles how to set a desirable level of global pollution and distribute the pollution right among countries in a fair way.

Irreversibility and Damages Which Cannot Be Assessed by Market

The price of some damages cannot be estimated as they will take effect only in a long term; their correction has not started yet and therefore, the cost cannot be defined. If these potential costs are not taken into account in the economic calculations, it may happen once, when they can be evaluated, they are irreversible. There is also another problem: how to put a price tag on non-market resources (e.g. plant and animal species which humankind does not use but destroys them)?

Actualization Rate

Eliminating pollution today - and so fight against damages in the future - creates the problem of actualization: it is necessary to compare two values which do not correspond in time (assuming their monetary evaluation has been solved).

It cannot be said that the economic theory has or does not have a reliable solution to fight ecological problems. This statement is used to console both, those who believe in market mechanism as well as those who doubt and suggest various moratoriums, regulations or even bans on activities which contribute to global pollution.

Monitoring of arising externalities is necessary with regards to the originator (polluter pays principle). To fulfil this basic principle is not trivial and the way from detecting emissions and pollutant dispersion to identifying the impacts, their natural valuation and finally monetary valuation is extremely complicated. The result is connected not only with high cost for the analysis itself but also with many uncertainties:

- Emission analysis itself (flow of the pollutants to the environment). The uncertainty here is relatively low, especially for basic polluting substances as many types of emissions are continuously or at least periodically measured based on the air protection law. Considering the influence of polluted air and origin of pollutants it is necessary to take into account very different local ratio of the polluting sources. For state of pollution it is necessary to expect significant deviations from the reality according to areas and at estimates of the basic background concentration.

- Behaviour and destiny of the pollutant in the environment - dispersion (transformation) of pollutants. The mechanism of the impact of atmospheric reactions to the state of the atmosphere is extremely complex and not fully explained yet.

- Dose - response function. The most frequent materials are epidemiological studies. For health evaluation as the most important segment of damages, reactions to some substances are not known yet. The function is usually assumed as linear due to missing LV (Limit Value) and the current concentration for other than basic polluting substances. Different outcomes of the influence may be expected for different ways of defining pollutant concentration. In contrary to our practice, emphasis has been recently put on ozone for impact on harvest, for nitrogen oxides the fertilizing function is assumed also for secondary compounds. Our local conditions also consider other agricultural crops as sensitive than in e.g. comparable conditions in Europe [5],[6]. Used methods for calculating damages in agricultural production, above all forests, in the Czech Republic form a standalone problem. So far the area of burden accumulation and especially problem of synergic impact of more pollutants has been researched very little. This latency of impact might be very significant e.g. for toxicological impacts.

- Economic valuation. Economic valuation is very significant for decision making; it reflects the scarcity and uses market prices, if they are known, readiness to pay, national economic accounting and the principle of external effect internalisation. The techniques used for evaluation in economic terms [14] may be divided into two groups - those where functional relation between pollutant dose and environmental response (damage function) can be found and those where a different solution needs to be found. Results of damage impact calculations derived from knowing natural damage have been published in the literature [3],[4],[12]. Most frequently these were damages from running energetic facilities, especially damages from air pollution and its impact on health of population and production (agriculture, forestry etc.). There are also newer methodical procedures based on population behaviour. This may be in form of direct methods: method of political referendum or contingent valuation method or indirect approaches: method of individual substitution, method of travel cost and method of hedonic price.

The problem of damage estimate also includes a link to the sustainable development principles [6],[10],[11]. These principles take the form of proposing not only narrowly defined utility value (either direct or indirect) but also existential value (given by the existence of the nature itself) and option value (ensuring the value of the nature for the future) in its wider conception about using all types of resources.

Damage may be also defined in cost necessary to remedy or prevent the damage. This alternative solution of the calculation based on the cost (real cost of the damage will not be found) may have various form: cost of avoiding the source of burden, cost of damage remedy, cost to prevent the damage, targeted prohibitive cost, defensive cost etc.

The text above was supposed to outline possible methods for quantification of activities and occurrences which concern humankind as a whole [2]. It is the problem of emission quantification, pollution and its impacts. In the end, we shall outline a few comments concerning this problem.

It has shown that the weak spot is monitoring the undesirable phenomena on one hand and publishing needed data in classification and structures which will have needed explicitness. The methodology of collection and processing such data is at its beginning [13].

III. EXAMPLE OF DATA AGGREGATION: VALUE, PRICE, QUANTITY

A. *The Whale and Its Parts*

Indicators are defined by attributes. The attributes include above all the meaning of the indicator, place and time.

The indicator is expressed by quantitative or qualitative characteristics.

If it relates to the whole, the indicator is specified as overall, aggregate etc. If it relates to a part of the certain whole, it is called partial, individual etc. Quantitative indicators have a dimension related to the meaning of the indicator. The dimension may be unit of currency, quantity etc.[7],[15], [16]. From the dimension character it is possible to determine if these partial (individual) indicators may be added together [9], [8].

B. *Value, Quantity and Unit Value*

Value and Quantity

Let us consider a whole which consists of n partial disjoint parts i, the unification of which gives the whole.

For each part i let us consider an indicator h_i. Let us assume that variables h_i are addable i.e. they have the same dimensions. We will call them values.

For each part let us assume variables q_i, which represent the number (quantity) of objects in the part i. The dimensions of these can be different, therefore, their sum may not make sense. These variables will be called quantity.

We will state

$$H = \sum_{i=1}^{n} h_i \tag{1}$$

We have obtained for each part two variables: value and quantity.

Unit Value

For the needs of further presentation we will set variables for each i

$$p_i = \frac{h_i}{q_i}. \tag{2}$$

The variables represent the value of item i for the unit of quantity for part i

If the value is expressed in monetary units, these variables represent prices. Generally, it may not be so, therefore, we will use term unit value.

For any h_i and positive q_i it can be said:

$$h_i = \frac{h_i}{q_i} q_i . \tag{3}$$

therefore, for any i holds true

$$h_i = p_i \; q_i. \tag{4}$$

variables h_i will form vector h

variables q_i will form vector q

Both of these vectors have *n* coordinates which correspond to the considered items. By aggregating the sum we will determine the total value in period t which will be marked as *H*. It holds true that

$$H = \sum_{i=1}^{n} h_i = \sum_{i=1}^{n} p_i \, q_i \quad . \tag{5}$$

A question arises whether it is possible to set numbers P and Q which correspond to vectors p and q so that following holds true

$$H = P \, Q \, . \tag{6}$$

Numbers P and Q will be called representatives of vectors p and q.

C. Changes of Data and Their Impact

From the above written relations results

$$dH = \sum_{i=1}^{n} dh_i = \sum_{i=1}^{n} \frac{dh_i}{h_i} h_i = \sum_{i=1}^{n} d(p_i \, q_i) = \sum_{i=1}^{n} (q_i \, dp_i + p_i \, dq_i) \tag{7}$$

$$\frac{dH}{H} = \sum_{i=1}^{n} \frac{dh_i}{H} = \sum_{i=1}^{n} \frac{dh_i}{h_i}\frac{h_i}{H} = \sum_{i=1}^{n} \frac{dh_i}{h_i} w_i = \sum_{i=1}^{n} \frac{d(p_i, q_i)}{p_i \; q_i} w_i \tag{8}$$

where

$$w_i = \frac{h_i}{H}. \tag{9}$$

This relative change of the total value is equal to weighted sum of relative changes of the values for individual parts. This leads to

$$\frac{dH}{H} = \sum_{i=1}^{n} \frac{p_i \, dq_i + q_i \, dp_i}{p_i \; q_i} w_i = \sum_{i=1}^{n} \left(\frac{dq_i}{q_i} + \frac{dp_i}{p_i}\right) w_i \tag{10}$$

Therefore, infinitesimal growth of value is equal to sum of weighted infinitesimal changes of unit value and quantity.

In order to express infinitesimal growth we will assume dependency of the variables on parameter t which will be assigned as an index to considered variables. Therefore, we will write

$$H_{t+dt} = H_t + dH_t \tag{11}$$

$$\frac{H_{t+dt}}{H_t} = 1 + \frac{dH_t}{H_t} \tag{12}$$

It arises from here that the index reduced by a unit represents relative change of variable H.

$$\ln \frac{H_{t+dt}}{H_t} = \ln H_{t+dt} - \ln H_t = \sum_{i=1}^{n} w_i (\ln q_{it+dt} - \ln q_{it}) + \sum_{i=1}^{n} w_i \, (\ln p_{it+dt} - \ln p_{it}) \tag{13}$$

$$\ln \frac{H_{t+dt}}{H_t} = \ln H_{t+dt} - \ln H_t = dln \, H_t \tag{14}$$

From which arises

$$\sum_{i=1}^{n} w_i \left(\ln \frac{q_{it+dt}}{q_{it}} + \ln \frac{p_{it+dt}}{p_{it}}\right) = \sum_{i=1}^{n} w_i \, \ln \frac{q_{it+dt}}{q_{it}} \frac{p_{it+dt}}{p_{it}} \tag{15}$$

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Let us mark

$$Q_t = q_{1t}^{w_1} q_{2t}^{w_2} \dots q_{nt}^{w_n} \tag{16}$$

$$P_t = p_{1t}^{w_1} p_{2t}^{w_2} \dots p_{n}^{w_{nt}} \tag{17}$$

$$\ln H_{t+dt} - \ln H_t = (\ln Q_{t+dt} - \ln Q_t) + (\ln P_{t+dt} - \ln P_t) \tag{18}$$

$$\ln \frac{H_{t+dt}}{H_t} = \ln \frac{Q_{t+dt}}{Q_t} + \ln \frac{P_{t+dt}}{P_t} = \ln \frac{Q_{t+dt}}{Q_t} \frac{P_{t+dt}}{P_t} . \tag{19}$$

Which emerges into

$$\frac{H_{t+dt}}{H_t} = \frac{Q_{t+dt}}{Q_t} \frac{P_{t+dt}}{P_t} \tag{20}$$

Variable P_t may be considered as aggregate variable of units values, i.e. as level of unit value and variable Q_t may be considered as aggregate variable of value.

D. Determining of Levels for Unit Values and Quantities

In this paragraph we will consider continuous time and infinitesimal time interval <t, t+dt).

This assumption leads to relations

$$dH_t = \frac{dH_t}{dt} dt \tag{21}$$

$$dp_{it} = \frac{dp_{it}}{dt} dt \tag{22}$$

$$dq_{it} = \frac{dq_{it}}{dt} dt \tag{23}$$

Variables

$$\frac{dH_t}{dt}, \quad \frac{dp_{it}}{dt}, \quad \frac{dq_{it}}{dt} \tag{24}$$

represent derivations of corresponding variables. These derivations represent intensity of changes of the respective variables.

A question arises whether it is possible to define a scalar representative of vector p_t which would represent level of unit value P_t and a scalar representative of vector q_t which would represent level of e Q_t so that holds true

$$H_t = P_t Q_t. \tag{25}$$

It is clear that P_t and Q_t do not have to be set in one way only. To prove this it is possible to consider any positive number and multiply one of the variables by this number and divide the other variable by this number.

We will stem from intensity defined by relation

$$\frac{d}{dt} H_t = \frac{d}{dt} \sum_{i=1}^{n} p_{it} q_{it} = \sum_{i=1}^{n} \frac{d}{dt} p_{it} q_{it} = \sum_{i=1}^{n} \left(p_{it} \frac{dq_{it}}{dt} + q_{it} \frac{dp_{it}}{dt} \right) \tag{26}$$

By deriving of the hypothetical relation

$$H_t = P_t Q_t. \tag{27}$$

by t, we will get

$$\frac{d}{dt} H_t = P_t \frac{dQ_t}{dt} + Q_t \frac{dP_t}{dt}. \tag{28}$$

It is natural that following holds true:

- if all derivations of coordinates of vector q_t are zero, also derivation of function Q_t is zero and coordinates of vector q_t are constants independent on t.

- if all derivations of coordinates of vector p_t are zero, also derivation of function P_t is zero and coordinates of vector p_t are constants independent on t.

This means that in the first case we will get

$$\sum_{i=1}^{n} q_{it} \frac{dp_{it}}{dt} = Q_t \frac{dP_t}{dt} \tag{29}$$

in the second case we get relation

$$\sum_{i=1}^{n} p_{it} \frac{dq_{it}}{dt} = P_t \frac{dQ_t}{dt} \tag{30}$$

if we divide mentioned relations

$$H_t = (q_t, p_t) = \sum_{i=1}^{n} q_{it} \, p_{it} = Q_t \, P_t \tag{31}$$

we get Divizov's differential equations

$$\frac{\sum_{i=1}^{n} q_{it} \frac{dp_{it}}{dt}}{\sum_{i=1}^{n} q_{it} \, p_{it}} = \frac{\frac{dP_t}{dt}}{P_t} \qquad \frac{\sum_{i=1}^{n} p_{it} \frac{dq_{it}}{dt}}{\sum_{i=1}^{n} q_{it} \, p_{it}} = \frac{\frac{dQ_t}{dt}}{Q_t} \tag{32}$$

The first equation corresponds to constant q_{it} and variable p_{it} , the second equation corresponds to constant p_{it} and variable q_{it} . These equations cannot be valid at the same time as in such case analyzing of changes in unit values and

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quantity would be unsubstantial. The solution of the equations leads to values P_t and Q_t . However, these values are not unequivocal.

By processing these equations we get

$$\sum_{i=1}^{n} w_{it} \frac{dp_{it}}{p_{it}} = \frac{dP_t}{P_t} \qquad \sum_{i=1}^{n} w_{it} \frac{dq_{it}}{q_{it}} = \frac{dQ_t}{Q_t} \tag{33}$$

where

$$w_{it} = \frac{p_{it}\, q_{it}}{\sum_{k=1}^{n} q_{kt}\, p_{kt}} \tag{34}$$

If weights w_{it} are constant in time, we can write

$$\sum_{i=1}^{n} w_i \frac{dp_{it}}{p_{it}} = \frac{dP_t}{P_t} \qquad \sum_{i=1}^{n} w_i \frac{dq_{it}}{q_{it}} = \frac{dQ_t}{Q_t}. \tag{35}$$

which leads to

$$\sum_{i=1}^{n} w_i \, d\ln p_{it} = d\ln P_t \qquad \sum_{i=1}^{n} w_i \, d\ln q_{it} = d\ln Q_t \tag{36}$$

By integration and setting integration constants $\ln K_P$ a $\ln K_Q$ we get

$$\sum_{i=1}^{n} \ln p_{it}^{w_i} + \ln K_P = \ln P_t \qquad \sum_{i=1}^{n} \ln q_{it}^{w_i} + \ln K_Q = \ln Q_t \tag{37}$$

after processing and delogarithming, we get relations for level of unit value which is a scalar representative of the unit values level

$$P_t = K_P\, p_{1t}^{w_1}\, p_{2t}^{w_2} \dots p_{nt}^{w_n} . \tag{38}$$

for level of quantity which is a scalar representative of the quantity level

$$Q_t = K_Q\, q_{1t}^{w_1}\, q_{2t}^{w_2} \dots q_{nt}^{w_n} \tag{39}$$

So we have got relations for sought price levels.

$$K_Q\, K_P = 1 . \tag{40}$$

IV. CONCLUSION

If gradually filled with data, the presented suggestion might become a suitable tool for aggregation of a huge amount of primary information which needs to be processed for decision making on higher levels of management. The first results will be presented on the macro-level.

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