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Values and Sciences in Service to Society[*]

Abstract

The absolute size as well as the relative fraction of resources and efforts that developed societies dedicates to science, research and scholarship makes it appropriate that scientists, researchers and scholars are addressing effectively and efficiently needs and challenges of the society. Choices are due when addressing effectiveness, efficiency or orientation towards challenges. Choices are driven by value-loaded notions, which are often inherent and implicit. Nevertheless they are influencing in what mode science, research and scholarship is delivered. Therefore they have to be put in a structured context to understand their interplay. Knowing how a particular „delivery mode" fits to the value setting in the society will ease understanding how science, research and scholarship could contribute effectively to well-being and sustainability. How „scientific services" are delivered is depending on scientist's choices in response to „value loaded notions", which in turn reflect functioning of a society. To analyse that response it is studied as a sequential coupling of sets of „value loaded notions". A mathematical framework is proposed this study, which eases analysis of relationships of „value loaded notions" and „delivery modes". The approach presented here is a means to reduce complexity for easing insight, e. g. in the internal consistency between various „value loaded notions" and preferred „delivery modes" for outcome of scientific work.

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Introduction – a multi-facet context

Contemporary societies need increasingly science, research and scholarship in order to maintain their sustainable functioning within the shifting natural, sociological and political environments. These shifts, which we experience, are driven by our particular ways of producing goods and services, which is stretching natural and societal resources available to mankind beyond sustainability. Independently whether outcome of science, research and scholarship will lead to a modification of our ways of producing, or will help to mitigate its consequences it should be of concern to us that our actions are based on scientific knowledge as far as possible. Therefore contemporary soci-

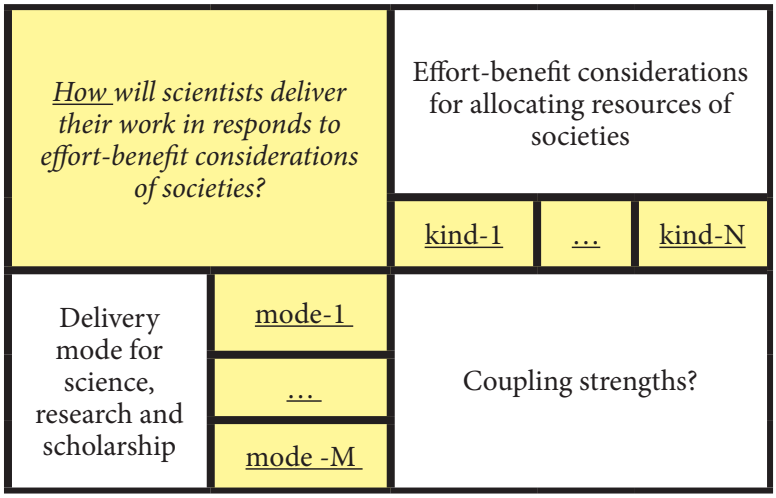

Figure 1; Coupling of effort-benefit considerations and delivery modes for science, research and scholarship

eties invest more and more of their economic product into professional activities of scientists, researchers or scholars; building what is called „knowledge based society". The scale of that investment is such that its effectiveness and efficiency also has a direct economic importance and social relevance [1], [2].

The economically developed countries have the political target to invest 3% of their gross domestic product into science and research [3]. That is comparable to one third of their spending on health issues. Total spending of economically developed countries into their knowledgebase (education, science, research and scholarship) is comparable to their total spending on health issues [4]. Investments of that size will have to show return on investment, otherwise

they will not be sustained. The expected return on investment can be delivered only by science, research and scholarship, when its activities address effectively and efficiently societal needs or challenges [5].

Societies will assess the relation between efforts put into science, research and scholarship and the benefits received in return. The efforts are the direct cost of investment and as well the indirect cost of other mainly non-material investments such as „recognizing status" or „granting participation rights". The benefits (tangible, non-tangible) are the output that science, research and scholarship can deliver for the functioning of the society. Scientists, researchers and scholars in turn will have to assess in what „delivery mode" they function or should function in order to meet public expectations; or when addressing societal needs or challenges. These two assessments are interrelated, in particular for a knowledge based society. The framework developed here describes this relationship as a coupling between „effort-benefit considerations" of societies and „delivery modes" of science, research and scholarship (fig. 1). The strength of the coupling describes what particular mode of delivery of science, research and scholarship will be seen as corresponding effectively and efficiently to effort-benefit considerations of societies, and therefore better suited to receive important investments. The framework developed here describes the coupling strength as a function of „value loaded notions" used by individuals and societies to govern their functioning.

It can easily be observed: scientists, scholars, managers of funding organisations, representatives of governing bodies (etc.) all operate with (many) notions that are value-loaded, when they argue how to foster science, research and scholarship. This kind of value loaded discourse reflects properly their understanding of the matter, their views on relevant structures of the society, and their concept or „programme" for advance [6]. A value loaded discourse is effectively communicating experiences and choices and therefore is appropriate. However the relatively high number of value loaded notions that are used simultaneously is an issue and consistency of their combined use seems less evident. Many scientists, scholars, managers of funding organisations, representatives of governing bodies are aware of that issue and resolve it by focussing on small number, or even single „value loaded notion". A prominent player doing such is the recently founded „European Research Council" that attempts to find success under the notion of „excellence" [7]; other players run under the notion of „innovation" [5].

Building a model

In this section an approach is set out, which shall model the coupling of „effort benefit consideration" of societies and „delivery modes" of science, research and scholarship applying value loaded notions. For convenience, these notions are named „driving factors", because they are understood to determine („drive") the modes of delivery. The „driving factors" selected for the model are: *„effort-benefit relations", „exchange modes", „incentives", and „consensus building"*.

The design of the model starts from the understanding that „delivery modes" for science, research and scholarship are rooted in the „exchange processes" that are operated in the society and such are reflecting „effort-benefit considerations" esteemed in this society. Furthermore it is understood that the „scientific services" are delivered by educated specialists, who react to „incentives", who participate at „consensus building", and who have their specific position within „exchange processes" of the society. That position in turn influences their response to „incentives" and attitudes regarding different forms of „consensus building". Thus when scientists refer *„how they like to deliver results of their work"* and take their choice as a combination of a creative act being like an „art", a „process" applying established methods to a chosen subject, a „product" designed to address a purpose, it is understood that this choice is made in a complex context, which maps back to the „effort-benefit relations" of the society.

Corresponding to the model a mathematical framework is formulated. It combines the „driving factors" using a bifurcated sequence of pair-wise mappings, which are described by matrixes. Starting from *„effort-benefit considerations*", two sequences of mappings are formulated to obtain *„delivery modes"* depending respectively either on *„incentives"* or on *„consensus building"*. The two sequences are combined into one equation. Thus, the first step in building the model is the mapping of *„effort-benefit considerations" to „exchange processes„;* the second (bifurcated) step are the mappings *„exchange processes"* to *„consensus building"* and *„exchange processes"* to *„incentives";* the third step are the respective mappings „consensus building" to *„delivery-modes"* and *„incentives"* to *„delivery modes"*. The forth step in building the model is to calculated the weighted sum of both sequences.

Matrices „DI, DC, IE, CE and EB" describe the mappings. These five matrices will be used to calculate the coupling between „delivery modes" and „effort-

benefit considerations", the matrix „DB". This matrix also will be guessed „ad hoc"; for comparison with the calculated results. The five coupling matrixes are called:

EB:	„exchange forms"	versus	„effort-benefit considerations"
CE:	„consensus building"	versus	„exchange forms"
IE:	„incentives"	versus	"exchange forms"
DC:	„delivery modes"	versus	„consensus building"
DI:	„delivery modes"	versus	„incentives"

The equation 1 describes how the coupling matrix „DB" between „delivery modes" and „effort-benefit consideration" is calculated. The symbol „*" describes a matrix product.

Equation 1:

$$DB = (1/n)\ DI * IE * EB + (1\text{-}1/n)\ DC * CE * EB$$

The positive number „n" is used to describe the relative dependence of the coupling between „delivery modes" and „effort-benefit considerations" on either the driving factor „incentives" or the driving factor „consensus building". The number „n" is positive and bigger or equal to one. The sum of both factors" (1/n)" and" (1-1/n)" is one; both factors have the same value (0.5) for „n" equal to two.

The model equation can be simplified (n=1) into a form (sub-model, equation 2. a) that describes the coupling between „delivery modes" and „effort-benefit considerations" depending on „incentives".

Equation 2. a:

$$DB = DI * IE * EB$$

For large values of n the model equation gets a form (sub-model, equation 2. b) that describes the coupling between „delivery modes" and „effort-benefit considerations" depending on „consensus building".

Equation 2. b:

$$DB = DC * CE * EB$$

The product „***IE * EB***" can broadly be interpreted as the model representation of economic relations of production, and the product „***CE * EB***" as the model representation of social relations of production. The products „***DI *…***" and „***DC *…***" can be interpreted as the model representation how scientists, researchers and scholars respond to these economic or social relationships in terms of the mode in which they deliver results of their work. The matrices „***DI***" and „***DC***" represent, respectively, the coupling of „delivery modes" and „incentives" and „delivery modes" and forms of „consensus building" (in the sector of the society in which scientists, researchers and scholars operate) and can be interpreted as a proxy for the response of the individual.

In order to build the matrices the „delivery modes" and „driving factors" have to be described. To keep it simple, each of them will be described by three features (Fig. 2), which are understood, as far as possible, to be mutually exclusive (or „orthogonal" to use a mathematical term) but shall give, in combination, a comprehensive description. In analogy: a physical space would be described by the features „length", „width" and „depth". Thus, the matrices „DI, DC, IE, CE, EB and DB" are structured in a simple manner (three columns, three lines); or in mathematical terms, the dimension of the matrix is three.

Following features are used to describe „delivery modes" and „driving factors":

– Regarding „delivery modes" for science, research and scholarship; they are understood (as already mentioned above) to come as a combination of three features, namely „science an art offered", or „science a process operated", or „science a product made".

– Scientists, researcher or scholars choose „what to do or what to leave" in function of their participation to the „consensus building" in the society, which may come in a combination of three features, namely „imposed" consensus due to external factors, or „inherited" consensus mediated through education or opinion building systems, or „adopted" consensus of the individual that is referring to internal reflections.

– Scientists, researcher or scholars respond to „incentives" given by the society which may come in a combination of three features, namely „income",

to make a living, or „status", in the society or among peers, or „satisfaction", e. g. to have followed an idea through.

– Societies provide „incentives" and arrange modes how „consensus is built" in context how „exchange processes[11]" are organised in the society, which may come in a combination of three features, namely „trading" of benefits and goods between groups or individuals balancing gains and efforts, or „steering" the distribution of benefits and goods using mechanism of soft or direct power, or „supplying" benefits and goods without knowing much who/how they will be taken up.

– Societies choose their mode of exchange processes in context of „effort-benefit considerations", which may come in combination of three features, namely „sustainable", when a comprehensive understanding is available how efforts and benefits relate without that losses accumulate in a hidden way, or „subvention", when understanding about relation of efforts and benefits is partial and incomplete, or „donation", when understanding about relation of efforts and benefits is less relevant than the purpose.

Matrix „AB"	factor-A feature-1	factor-A feature-2	factor-A feature-3
factor-B feature-1	high/ medium/ low	high/ medium/ low	high/ medium/ low
factor-B feature-2	high/ medium/ low	***making best guesses***	high/ medium/ low
factor-B feature-3	high/ medium/ low	high/ medium/ low	high/ medium/ low

Figure 2 Schemata of coupling between factor A and factor B, each having three features

Having described the structure of the transfer matrices the next step is now to give each cell in each matrix a value, which shall describe the specific coupling strength. In order to keep it simple, qualitatively the coupling strength may be high, medium or low (Fig. 2). The figure 3 shows the choices for the different matrixes, which were made to set a „baseline scenario". The „baseline scenario" is set „ad hoc". Further research in more systematic choice of

[11] Economic and non-economic

DI	Income	Status	Satisfaction
Product	high	low	low
Process	medium	medium	medium
Art	low	medium	high

DC	Imposed	Inherited	Adopted
Product	low	medium	Low
Process	low	medium	Medium
Art	low	low	high

IE	Traded	Steered	Supplied
Income	high	medium	low
Status	medium	medium	medium
Satisfaction	low	low	medium

CE	Traded	Supplied	Steered
Imposed	low	low	medium
Inherited	medium	medium	medium
adopted	high	high	low

EB	Sustainable	Subvention	Donation
Traded	medium	low	low
Steered	medium	high	medium
Supplied	low	medium	medium

Figure 3. Coupling Strengths “Baseline Scenario” – Matrixes DI, DC, IE, CE and EB

coupling strength will be needed. In the context of this study this baseline scenario is for the purpose of illustrating the functioning of the model and the kind of analysis, which could be made using the model. Regarding technical aspects of the model it can be noted that general pattern of results does not differ much if the numerical values of the coupling coefficients for coupling strengths low, medium or high are set to „0.01, 0.1, 1.0" instead of „0.1, 0.3, 1.0"; as used in the following. Furthermore it is not necessary that the features are „orthogonal" in a strict mathematical sense but values of the coupling coefficients could be chosen independently if features having that characteristic. The matrixes may have a higher dimension than three, when it is chosen to describe each factor by more than three features (for example: four, five…) but such a choice would make the analysis more complex. All matrixes have been normalised (absolute norm) before calculations are done to give each matrix the same relative „weight" (one).

Results and Discussion

The results presented here are limited to illustrate applications of the model and its underpinning concepts. Interpretation of model results is only hinted to, because it should await further scrutiny of the model, and it will need more specialized sociological, political, psychological and historical understanding to set the matrixes for different scenarios.

The first analysis of the baseline scenario is to compare the „guessed" coupling strengths for the matrix „DB" („delivery modes" versus „effort-benefit considerations") with the „calculated" coupling strengths. It is to recall that all values for the transfer matrixes of the baseline scenario are set to best understanding and to be consistent, but in the end they are estimates.

The outcome of the comparison is that the „guessed" matrix „DB" and the „calculated" matrix „DB" are different (fig. 4). To provide a numerical comparison: the „delivery modes" are calculated[12] to have relative strengths 0.29 (product), 0.27 (process) and 0.44 (art) but their guessed values are 0.21 (product), 0.52 (process) and 0.25 (art).

The differences between guessed and calculated values seem particular big for the delivery mode „art" and effort-benefit consideration „subvention". Thus

[12] Sum of coefficients of each line of the matrix weighted so that the sum over the matrix is one.

the settings for the matrixes „DI, IE, DC, CE, EB" and „n" in the „base line scenario" are inconsistent with the ad-hoc setting for matrix „DB".

Variations around the baseline scenario are explored in order to understand how variable the calculated coupling strengths of the matrix „DB" are. A total of 49 different slightly different scenarios for setting the values of matrixes „DI, DC and CE," were chosen[13] and nine different values for „n". This gives

Guessed DB	sustainable	subvention	donation
product	medium	low	low
process	medium	high	medium
art	low	medium	medium

Calculated DB (baseline, n=2)	sustainable	Subvention	donation
product	medium	high	medium
process	medium	high	medium
art	high	high	high

Figure- 4: Comparison of guessed and calculated Matrix „DB" („delivery modes" versus „effort-benefit considerations") – in qualitative representation (high, medium, low)

441 scenarios, which were scrutinized whether some scenarios are found for which the „guessed" and „calculated" coupling coefficients of the matrix „DB" are similar, thus respective settings of coupling strengths are consistent. Such scenarios are found when:

– The value of „n" has been chosen such that the response to „incentives" compared to the response to „consensus building" is such that scientists react stronger to „incentives" (at least twice as strong) than to „consensus building"; *and*

[13] The matrixes „IE" and „EB" were not varied. They represent in the model the economic side of the relationships and would require separate considerations about variations.

– either for response to „incentives" the reaction to the incentive „status" has to be stronger than that to the incentive „income" or for response to „consensus modes" the reaction to the form „adopted" has to be weaker than to the forms „imposed" and „inherited".

Thus, in terms of the model, the guessed coupling of „effort-benefit considerations" versus „delivery modes" would be consistent with a value setting in which response to the „incentives" is relatively important, in particular if the driving incentive is „status"; and the „consensus building" is driven mainly by education and other external factors.

N	**1,00**	**1,25**	**1,33**	**1,50**	**2,00**	**3,00**	**5,00**	**10,0**
Sub-model 1 (incentives)	1	4	3	2	1	1	1	1
versus	v.	v.	v.	v.	v.	v.	v.	v.
Sub-model 2 (consensus building.)	0	1	1	1	1	2	4	9
product	0,33	0,30	0,30	0,28	0,26	0,24	0,22	0,21
process	0,41	0,37	0,36	0,35	0,32	0,30	0,28	0,27
art	0,26	0,32	0,34	0,36	0,41	0,46	0,50	0,52

Table 1: Average weight of „delivery modes" for different values of „N", which determines relative weight of sub-models.

When comparing the different scenarios it is found that the choice of the numerical value for „n" (relative weight of sub-models) is relatively important compared to variations of numerical value of some coupling strengths for a fixed value of „n". Therefore average scenarios were built by keeping the value of „n" fixed and averaging over the 49 scenarios for different coupling strengths. It is found that the average relative weight of the three „delivery modes" is varying smoothly depending on value of „n". The model indicates a shift from the delivery mode „product" towards the delivery mode „art"

for increasing values of „n", thus when response to „consensus building" is getting stronger compared to the response to „incentives" (Table 1). Such a shift would reflect a situation in which modes how scientists, researchers and scholars deliver outcome of their work would depend more on how consensus is found in the society than on incentives that are provided.

The model indicates that the relative average weight of the three delivery modes (product, process, art) is about the same when the weight of „incentives" to „consensus mode" is set to be 3 to 1 (n=1.33). For that particular case „delivery modes" dependent mainly on either the strength given to the consensus form „adopted" and or on the form of the incentives. Regarding the latter it is found for example that for a single strong incentive „income" the preferred delivery mode is „product", that for a single strong incentive „status" the preferred delivery mode is „process", and that for a single strong incentive „satisfaction" the preferred delivery mode is „art". This latter outcome may be understood to reflect a situation in which economic and social needs seem satisfied and therefore are no driving factors anymore, and internal driving factors are getting more important.

The results presented in this section shall illustrate what kind of descriptions and analysis could be made using an apparently simple and mechanistic model[14]. However the model is not such simple. In spite of its limited degree of complexity, namely matrices of dimension three and three possible values for each coupling coefficient each matrix has as many, slightly different settings. That provides scope to the model to cover a wide range of configurations. It is a challenge for further study to design a strategy to select meaningful configurations; for each matrix and for their combination. A first step would be to limit setting of coupling strengths to binary values only – on/off. Doing so will reduce the number of different setting of each matrix from 19683 to 512.

Conclusion and Outlook

An approach and a mathematical model have been developed to describe multi-facet relations of value loaded notions, which set *„driving factors"* for modes in which outcome of scientific work may be delivered (*„delivery modes"*). A sequence of mappings is the core of the approach. The mathematical model was kept simple (dimension three for matrixes that describe the mapping) but

[14] The mathematical model (Excel-workbook) is available on request from the author.

more complex models (higher dimension for matrixes) are consistent with the approach.

The model was applied in a configuration in which three different modes *„how outcome of scientific work may be delivered"* are known; namely: *„science an art offered"*, *„science a process operated"* and *„science a product made"*. A baseline scenario of the *„driving factors"* was set and varied to test relationships. The analysis indicated, e. g., that *„effort benefit considerations of subvention type"* relate well with concept of *„scientific services delivered as art"* if the response of scientists and scholars to *„incentives by income"* is relatively weak compared to other driving factors. Other patterns of *„effort benefit considerations"* and *„delivery modes"* are more related when *„consensus building"* of the individual scientist is driven by education and opinion building processes of the society. Furthermore, indication was found that shifting the *„effort benefit consideration"* towards the mode *„sustainable"* moves the delivery mode of *„scientific services"* more towards the mode *„product"*.

Putting these preliminary patterns aside, the setting for the baseline scenario for the model and the manner how its variations are set and interpreted needs more scrutiny. However within these limitations, this study showed what kind of analyses and descriptions are possible using the approach / model presented here. In particular, it has been illustrated how the model could be used to assess consistency of multi-facet relations of value loaded notions in relation to the *„delivery modes"*, which they are driving.

It is considered that the model presented here provides a robust and flexible framework to gauge value-loaded relationships and embedded functioning of science, research and scholarship. Developing such frameworks will facilitate that science, research and scholarship gains culture and status of an effective, efficient and sustainable service, which is assisting societies to face their challenges.

To nurture a service culture deems necessary, simply because of the size of investment, which societies make to foster science, research and scholarship throughout the value chain – from blue-sky curiosity driven research or frontier research to demonstration projects. Appropriate return on investment is due or else societies will curb that investment, because doing differently may not be sustained when it goes beyond their immediate carrying capacity.

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