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THE FUTURE OF SYSTEM DYNAMICS:

ABOVE OR BENEATH ECONOMETRICS–

OR WHERE ELSE?

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INTRODUCTION

Since its beginning as "Industrial Dynamics", System Dynamics (SD) has been under attack from followers of other modeling methodologies - at first mainly operations researchers and later (since "Urban Dynamics" and "World Dynamics") economists and econometricians (EC). In the last years system dynamicists have launched some heavy counterblows not only to refute the EC-criticisms but also in order to prove that EC more than SD is afflicted with severe flaws. Although there have been some attempts of unprejudiced comparisons of both modeling approaches (e.g. [1] [2] [3] [4]), "the present situation is such that nonadverseries, i.e. neutral observers, find it difficult to assess the value of system dynamics (and competing methodologies) to them" ([5] p. 23). Nevertheless at least two agreements seem to have emerged:

- in the field of dynamic, socio-economic modeling and simulation econometrics and system dynamics are the most important competitors (microanalytical simulation left aside)
- this competition has to be carried out on a general methodological and not on a model-specific level because criticisms against certain models (right or wrong) never refute or corroborate the approach as such; model-specific objections can only illustrate approach-general objections.

There seem to be two advantages in starting with a comparison of the SD and EC methodologies rather than a SD and an EC model. First, comparing a SD and an EC model - e.g. of the labor market - leaves one with the troublesome decision if the differences in results are due to the underlying modeling philosophies or simply to the consequence of different problem definitions, conceptualizations of the research questions, theories and data employed (problem of attribution). Only if all these latter factors influencing the specification of comparable SD and EC models could be held constant - a kind of ceteris paribus clause - would the comparison of specific models allow for inferences about the methodologies. Second, similarities as well as distinctions between certain SD and EC models may solely rest with these two models and may not be found in others (problem of generalisation). On the other hand the knowledge obtained from a general confrontation of modeling approaches should render valuable guidelines for further comparisons of specific models.

The purpose of this paper is therefore to contribute to a broad comparison of the SD and EC concepts - withstanding from commenting certain modeling efforts - and to a clarification of the conceivable future relations between these two fields of research in socio-economic simulation. We do not hold the views expressed here to be the "last word" on this matter but rather hope to give an impetus for systematic discussions.

COMPARISON OF MODEL FEATURES

Let us start with an indication to some common basic believes of EC and SD. Both conceive the reality of modern socio-economic systems to be so highly complex that mathematical models are held to be far superior devices for predictions and decisions than verbal or mental models. They also share the preoccupation with dynamic phenomena of these system - fluctuations, growth, stagnation and decay. It should further be recognized that both EC and SD are macroanalytical in the sense that they do not model real systems on the level of their elements (individuals, households), tracing changes of certain characteristics of these elements over time and aggregating them in order to describe the changes in system behaviour, but rather model systems by variables which describe the characteristics of a sum of elements belonging to the same class ([6] pp. 30-39). These overlappings seem to be the rationale for the SD-EC-rivalry which does not exist between two much more distinct modeling approaches like SD and critical path methods or event-oriented simulation methodologies. These differences in competitative strength are also reflected in Donella Meadows' "Unavoidable A Priori", where four modeling methods are exposed (SD, EC, Input-Output Analysis, Optimization) but only SD and EC are seen to be involved in a "paradigm conflict" ([1] pp. 222-236).

These similarities should not be overlooked while stressing the differences between EC and SD. Due to limited space we cannot comment on all model features held to be relevant and abbreviated in Table 1. Because some authors have lately recommended partial modifications of SD we have introduced the distinction between Classical System Dynamics (CSD), as advocated by Forrester since "Industrial Dynamics" [7], and Modified System Dynamics concepts (MSD). Since it is impossible to reproduce our in-depth assessment of these model characteristics and of the justification advanced by EC and SD - see [8] for a detailed treatment - we have to confine to an exemplary and short-cut exposition.

Sources Of Information

It is well-known that CSD heavily rely on expert opinion, intuition, and personal acquaintance of the real system as information base for model specification while EC favors economic theory and available data. Nevertheless both seem to mutually move towards each other: while SD - especially as applied in macroeconomic modeling ([3] [9] [10] [11] [12]) - gives more scope for economic theory and data considerations, EC modelers nowadays admittedly employ subjective expert judgement to adjust constants and coefficients in order to improve their forecasts ([13] p. 520, [14]). There remains the difference, though, that EC models require time-series data mainly for variables - for all variables in the parameter estimation phase and specifically for the exogenous variables in ex-post simulations - while SD models need data primarily for inital level values and for parameter measurements, as far as they are directly observable.

Degree Of Hardness

The above comments on data requirements in connection with the aspired degree of accuracy (Tab. 1, 15.) already suggest why the emphasis of EC is on quantitative and observable variables although not strictly excluding qualitative variables (dummies) or unobservables (e.g. proxies). The more liberal usage of unobservable variables in SD allows for an easier incorporation of "planned" or "desired" variables thus facilitating the modeling of disequilibrium mechanisms [15]. Here again we observe signs of reduced differences between EC and SD as within the former the "soft modeling approach" gains ground [16].

Types Of Equations

Both EC and SD models exist of behavioural and definitional identities. Differences in the structure of behavioural equations are reflected in features 5.-8. of Table 1. In SD models definitions appear mainly in the form of stock-flow identities (level equations), which is justified with the importance of the principle of conservation ([17] [18]), while in EC models they are mostly national income identities (relating flows to flows). We feel that these differences are not primarily rooted in contradictory "world views" about conservation or non-conservation of flows in real systems, but can rather be traced back to other model characteristics. Economic and social statistics generally contain more and better data on flows than on stocks which are often unobservable and

MODEL FEATURES	EC	SD	
		CSD	MSD
1. SOURCES OF INFORMATION			
a. socio-economic theory	d	p	p
b. expert experience etc.	p	d	p
c. data	n	p	n
2. DEGREE OF HARDNESS			
a. quantitative variables	d	p	p
b. qualitative variables	p	p	p
c. observable variables	n	p	n
d. nonobservable variables	p	p	p
3. TYPES OF VARIABLES			
a. physical variables	-	n	-
b. informational variables	-	n	-
c. stock variables	p	n	p
d. flow variables	d	n	n
4. TYPES OF EQUATIONS			
a. behavioural equations	n	n	
b. definitional identities, e.g.	p	n	
ba. stock-flow identities	p	n	
bb. national accounting identities	d	p	
5. TYPES OF BEHAVIOURAL EQUATIONS			
a. deterministic	-	d	p
b. stochastic	n	p	p
6. FUNCTIONAL FORMS			
a. linear in param. and var.	d	(p)	p
b. nonlinear in parameters	(p)	p	p
c. nonlinear in variables	p	p	p
d. nonlinear in param. and var.	-	d	-
7. TIME INTERVAL			
a. statistic model	-	-	-
b. dynamic model	n	n	n
ba. discrete model	d	p	d
bb. quasi-continuous model	-	d	-
bc. continuous model	(p)	-	-
8. LAGS			
a. fixed-time lags	d	p	p
b. distributed lags	p	d	p
ba. finite distributed lags	p	-	p
bb. infinite distributed lags	p	d	p
9. MODEL BOUNDARY			
a. closed model	p	n	p
b. open model	d	-	p
10. CAUSAL ORDERING			
a. recursive model	(p)	n	d
b. block-recursive model	d	-	p
c. interdependent model	p	-	p
11. FEEDBACK STRUCTURE			
a. output-closed	d	d	d
b. output-open	p	-	p
12. PARAMETER ESTIMATION			
a. ad hoc	-	n	p
b. econometric methods	n	-	p
13. EVALUATION			
a. non-predictive evaluation	p	-	p
b. predictive evaluation			
ba. deterministic evaluation			
baa. ex post (explanation)			
baaa. static	p	-	p
baab. dynamic	p	p	p
bab. ex ante (prediction)			
baba. static	(p)	-	(p)
babb. dynamic	d	p	d
bb. endogenous simulation	p	d	p
bc. stochastic simulation	p	p	p
bd. backward simulation	-	-	(p)
c. policy evaluation			
ca. ex post (explanation)	p	p	p
cb. ex ante (decision)	d	d	d
cc. change in instruments	d	p	p
cd. change in specification	p	d	p
ce. optimization	p	-	p
14. TIME HORIZON			
a. short-/middle-term	d	(p)	p
b. long-term	p	d	p
15. DEGREE OF ACCURACY			
a. high	d	-	p
b. low	-	d	p
16. MAIN MODEL PURPOSE			
a. obtaining knowledge of parameter magnitudes (elasticities, propensities, multipliers)	p	-	p
b. testing economic theories	p	p	p
c. precise prediction of variables	d	-	p
d. general understanding of dynamic behaviour	p	d	p
e. improvement of model (and real system) behaviour	p	p	p

EC = Econometrics; SD = System Dynamics; CSD = Classical System Dynamics; MSD = Modified System Dynamics concepts; n = necessary; d = dominant; p = possible; (p) = possible, but seldom used; - = unimportant or impossible

Table 1: Comparison of Econometric and System Dynamics Model Features

therefore excluded from EC models (→ Tab. 1, 2.). On the other hand the importance of stock variables for the dynamic behaviour of a model increases with the length of the time horizon to be simulated. This is another reason why EC models do not lay as much stress on stocks than SD models normally do (→ Tab. 1, 14.). Furthermore it must be recognized that some macroeconomic SD models are themselves not immune from lack of stock variables (e.g. [3] [19]).

Functional Forms

Although EC has never claimed that linear functions are the only way of interrelating variables (see [20] [21] [22] for a very early controversy on this subject and [8] pp. 51-55 for a comment) there is no doubt that nonlinearities only played a minor part in first-generation EC models. After problems of estimating and solving nonlinear EC models with simultaneous equations had become easier to handle, the "world view" of EC shifted towards a fuller recognition of the relevance of nonlinear functions. Since the 1960's "neither we nor the practicing econometrics profession really believe that the economy can be adequately represented by a linear model" ([23] p. 9). This is very much in line with convictions held by CSD from the outset. In spite of this advancement of EC in the SD direction there still remain two differences. First, the portion of nonlinear equations within EC models seems to be smaller than within SD models on the average. Second, the forms of the nonlinearities employed are not congruent. While SD models incorporate piecewise linear table functions (TABLE, TABHL) which render equations nonlinear in parameters, EC models overwhelmingly use nonlinear-in-variables formulations. But here again we observe narrowing gaps. Today DYNAMO offers a nonlinear-in-variables table function TABPL ([24] pp. 34-35) for SD models, while EC has started to deal with varying-parameter models [25]. Another perspective of similar treatment of nonlinearities emerges with the incorporation of linear and cubic splines in EC models [26] as well as in MSD models ([8] pp. 185-187, 380-382).

Lags

Figure 1 demonstrates that SD delays can be regarded as a portion of the larger set of EC lag structures. Actually SD delays are the quasi-continuous counterparts of the geometric and Pascal lag distributions. For DT = 1 both groups become equivalent ([8] pp. 206-207). Although it is often very plausible that the output of a certain process will be distributed over time relative to its input there is no reason to neglect the existence of other kinds of dynamic processes with fixed-time lags. In the early days of SD (e.g. [7] p. 91) they appeared as so-called pipeline delays and were represented in DYNAMO I as BOXLIN functions. Later they were discarded from SD [17] as well as from DYNAMO II. Today they are resurrected in the simulation language as SHIFTL functions but the SD methodology has not yet reestablished them. In EC models these fixed-time lags always played a dominant role. Another major difference between EC and SD exists within the group of distributed lags. While SD only knows infinite lag distributions EC also use different types of finite lag distributions, partly with and partly without a priori restrictions on their parameters.

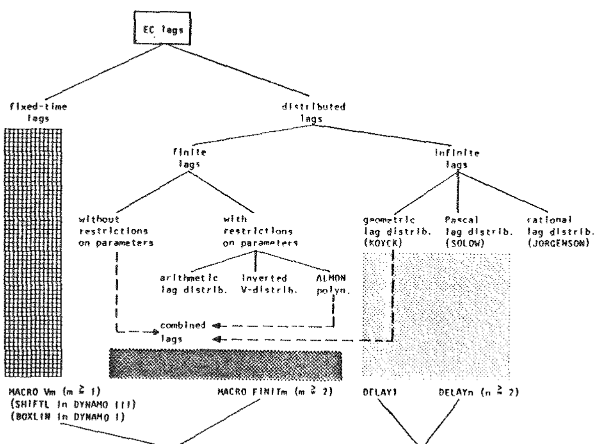

Figure 1

Two kinds of modifications of the CSD treatment of time-lags have been suggested:

1. the use of econometric estimation techniques to determine the order and average delay DEL of SD delays [27]
2. the transfer of EC finite-distributed lag forms to SD.

With regard to the first point two strategies are conceivable:

1.a. estimation of the appropriate Koyck distribution (for a DELAY 1) or Pascal distribution (for a DELAY of higher than first order)

1.b. estimation of a finit lag distribution and afterwards approximation by an appropriate DELAY.

We have demonstrated that the second strategy can be successfully followed by estimating an arithmetic lag distribution as a basis for a DELAY 1 and an Almon distribution with a polynomial of second degree for a DELAY n (n >= 2). Another interesting perspective is the estimation of an Almon distribution with a polynomial of fourth degree possibly leading to a bimodal lag distribution which can be approximated by a combination of different DELAY's ([8] pp. 209-217).

If one is ready, however, to employ a finit lag distribution mainly just to get an empirical estimate of the average delay DEL, it is worth-while to consider a complete incorporation of the estimated Almon lag distribution in the model. An adequate DYNAMO-Macro has been formulated by Zwicker ([28] pp. 514). One should recognize though that with a varying time increment DT the definition of the average delay DEL only holds for CSD exponential DELAY's. The transfer of fixed-time and finite-distributed lags into a MSD concept requires to drop the DT-variability and makes therefore only sense together with another modification: the shift from quasi-continuous to discrete SD models (→ Tab. 1, 7.).

Model Boundary

One of the severest differences between EC and CSD models is their very dissimilar tolerance for exogenous variables. It would be misleading, though, to assert that these differences are mainly caused by the philosophical question, if real systems are open or not. In fact, the "world views" are rather close together here. While CSD allows for exogenous variables only "where the external input is completely independent of and unaffected by any of the variables generated in the model" ([7] p. 113), EC requires not complete but only approximate independence ([29] p. 394). The fact that CSD models are closed and EC models are usually open (with different degrees [8] p. 223) is above all due to disagreement on the proper model purposes to be pursued (→ Tab. 1, 16.). "System dynamicists are generally unconcerned with specific values of system variables in specific years. They are much more interested in general dynamic tendencies; whether the system as a whole is stable or unstable, oscillating, growing, declining or in equilibrium" ([1] pp. 176-177). The apparent trade-off between endogenity and predictive capabilities of a dynamic model - already recognized in [7] p. 113 - leads EC models to treat those variables as exogenous which can externally be predicted with greater accuracy (→ Tab. 1, 15.). Two misunderstandings should be avoided though. The use of exogenous variables does not necessarily and exclusively imply that they are fed with real data([7] p. 113) but they may be - even ex post - and must be - ex ante - formulated as functions of time. It further follows that the internal dynamics of an open model can just as well be analyzed by endogenous simulations (→ Tab. 1, 13c.) as those of a closed model if one holds the exogenous variables constant or treats them as simple functions of time.

Finally, it should be mentioned that some departures from the CSD closed boundary concept can be observed. Some models, e.g. those developed by Lehmann [3] and Blackman [30], make use of exogenous variables. Two MSD concepts have suggested a general methodological shift in this respect: "Probalistic System Dynamics" [31] includes probalistic outside events while Zwicker's "Feedback-oriented Open Level-Rate"-modeling (FOLR) allows for exogenous variables more along traditional EC lines [28].

Causal Ordering And Feedback Structure

It is well-known that circular causal relations in CSD models must always pass through a level implying a lag of length DT and thus prohibiting the occurence of simultaneous interdependences between two variable. This has been justified by the "principle of independence of decisions" but the central motive probably was the easier computional handling of recursive than interdependent models ([7] p. 70). It is interesting to register that although the alternative "interdependence versus recursiveness" has been one of the oldest methodological disputs within EC (see [32] for a survey), SD-proponents have never drawn on the arguments which the advocates of recursive EC models had raised. "Our main conclusion, therefore, is that if the model is made sufficiently detailed and appropriatly specified, and if the periods are sufficiently short - i.e. if we work with a basic model constructed on the principles of the "disequilibrium" method of the Stockholm-school - the model can always be made recursive, and, indeed, must always become recursive ([33] p. 160). This fits very well with CSD views.

EC has nevertheless very much favored interdependent models. "While most builders of econometric models use an interdependent system, and have, as a result, accumulated much empirical evidence, virtually all of the debate has consisted of criticism of interdependent systems by proponents of recursiveness who bring to battle an imposing array of conceptual and theoretical arguments, but very little empirical evidence" ([32] p. 119). The above quoted statement by Bentzel and Hansen already indicates the circumstances which can lead to simultaneous interdependences in dynamic models:

1. aggregation over time due to a sampling period longer than the decision period
2. aggregation over individual decision units and over economic goods causing a loss of "sufficient detail"
3. static equilibrium conditions and definitional identities.

The first point reflects the indirect influence of the primary decision, if the parameters should be estimated formally or not (→ Tab. 1, 12.), on the causal ordering, because the sampling period of most economic time-series data is seldom shorter than a month, usually a quarter (→ Tab. 1, 7.). This implies that macroeconomic SD models with formally estimated parameters cannot per se rule out simultaneous interactions. An analogous argument can be put forward with respect to the second point. The relevance of the third point can be demonstrated by a quote from a report on a SD model of the German economy: "We used a smoothed average of GNP to compute the demand for intermediate inputs in order to avoid simultaneity between equations 59 and 61" ([3] p. 151). All in all we feel that the enforcement of a priori recursiveness would be hard to defend in the case of discrete, macroeconomic MSD models. This does not contradict our opinion that recursiveness would be a desirable property even of discrete MSD models because it allows for better causal interpretation of the single equations. We are just skeptical that it can be achieved and therefore prefer to regard recursiveness rather as an heuristic principle than an obligation.

While the causal ordering gives insights into the intraperiodic (inter-)dependences between the endogenous variables the feedback structure reveals the inter-periodic causal relations. By this criterion we distinguish dynamic models into output-closed and output-open if all endogenous variables contribute to the explanation of at least one other variable resp. if one variable does not. The main difference is not between finished EC and SD models, because almost all of their endogenous variables are part of dynamic feedback loops. The real distinction is of heuristic nature. While SD model building concentrates on the detection of feedback loops from the very beginning, EC model building starts with the specification of a variety of single equations and afterwards takes a look at the feedback loops which have resulted.

Parameter Estimation And Evaluation

We have given relatively broader scope for the features concerning model specification because they have usually not gained as much attention as the highly controversial issues of parameter estimation and non-predictive evaluation. We will sustain from commenting on these really complex topics and refer the reader to [34] and [8] pp. 244-291, 298-299. Only the two major logical connections to other characteristics should be mentioned here. CSD believed that statistical parameter estimation methods were superfluous because of

1. the qualitative insensitivity of model behaviour to most parameter values which is understandable only on the grounds of the SD model purpose (→ Tab. 1, 16d.)
2. the direct observability of parameters from the real system.

EC on the other hand needs precise parameter values (→ Tab. 1, 16c.) and assumes that variables are more likely to be observable than parameters (→ Tab. 1, 2.). In the last years the CSD aversion against statistical estimation and testing of parameters has even sharpened. Instead of regarding them as superfluous but harmless [7] they are now attributed to even render "major errors in estimates of parameters" and "misleading indications from internal measures of validity" [35]. This point of view is clearly contradictory to a cornerstone of the EC methodology.

A general agreement exists between EC and SD that evaluation is a problem- and purpose-oriented procedure aimed at improvement of models. But because of differences in the model purpose itself this unison should not be overestimated. EC and SD not only differ on the relevance and methods of independent validation of parameters and specification but also on the kinds of simulations employed for predictive evaluation (→ Tab. 1, 13b.). Finally, SD and EC put different emphasis on policy simulations. The former models try to achieve better long-run behaviour modes by changes in the model structure while the latter look for meeting certain quantified values of target variable by changing some instrumental parameters or variables.

CONCEIVABLE RELATIONS BETWEEN ECONOMETRICS AND SYSTEM DYNAMICS

Recurring on Table 1 and the above explanation we can now systematize the relations between EC and SD which have been forwarded by different authors.

Equivalence

There is obviously no equivalence in the structure, specification and quantification of EC and SD models (→ Tab. 1, 1-12). Some model builders speak of equivalence in a wider sense, though, expressing their conviction that qualified econometricians and system dynamicists should be able to tackle the same problem equally well. Looking at the different model purposes of EC and SD we can hardly agree with this view.

Dominance

A relation of dominance would exist if one approach would emerge to be superior for all possible uses of dynamic models in all conceivable fields of applications (dominance by superiority). This seems to be the more or less hidden persuasion of most EC as well as SD followers. The rigour of many EC criticisms of SD models like "Urban Dynamics" or "World Dynamics" apparently implies the inferiority of the SD methodology in whole. Even economists who have taken a more refined stand are in danger of such a view. "... my main grievance with Forrester is the way, in which he has chosen to apply his methodology, rather than with the methodology per se" [36]. In spite of this, Naylor's suggestions for a sound world model would not lead to a "better" application of SD but rather to a typical econometric model. A systematic proof for the superiority of the EC over the SD methodology has to our knowledge not yet been presented.

System dynamicists, on the other hand, had proclaimed a hegemony of their approach simply because no other modeling approach was believed to be in sight - in spite of thirty years of applied econometrics (dominance by lack of competition). "Until recently, there has been no way to estimate the behaviour of social systems except by contemplation, discussion, argument and guesswork" ([37] p. 212). This attitude has changed in recent years recognizing the existence and potential usefulness of EC models. "We believe there is an excellent chance that a comprehensive system-dynamics model ... can complement other approaches and can fill in where other methods of analysis have been unable to answer important questions." ([35] p. 125). Nevertheless this perspective of complementarity (→ cooperation) remains vague as long as it is not made explicit under which conditions EC models would be preferable. From Forrester's catalogue of SD advantages it may be concluded ex negativo that EC models are regarded to be superior for accurate, short-term predictions. But even this partial superiority of EC models, which is a prerequisite for actual complementarity, is doubted by other SD authors. If one believes that forecasts without any models are better than EC predictions and that "naive models" do as well as EC models ([38] p. 233), than there again remains no scope for this approach (dominance by superfluousness of the competing approach). Here, too, we think that the maintained dominance of SD has not yet been and probably will never be prooven. The easiest way to defend the dominance of either approach would be if one methodology could be shown to the more general in structure and in range of applications. This seems to be impossible (→ Tab. 1).

Convergence

While we have dealt with equivalence and dominance as relations between mainstream EC - often referred to as EC in the Cowles Commission tradition - and CSD as founded by Forrester, it is also possible to confront EC and SD not in a static but in a dynamic way by including the internal developments, extensions and modifications of both. We speak of a convergence, if these internal developments increase the intersection of common model features. The convergence will be called one-sided, if it only affects either EC or SD, and two-sided, if both are involved. We will further distinguish between a convergence with a tendency towards equivalence, if the approaches become very much alike, and of a convergence with a tendency towards dominance, if one of the approaches will be absorbed by the other. Looking at Table 1 it is easy to imagine the numerous possibilities of isolated changes in certain model features. We have documented some of the proposed modifications of SD in the MSD-column. One has to pay attention to the interconnections between the model characteristics.

Two-Sided Convergence. An example for this variant of convergence is the research strategy pursued by a group which has built a model of HESSEN (a state of the FRG). The underlying philosophy stems from the recognition that the theoretical background and the amount of data available are very dissimilar for different socio-economic subsystems [39]. The cornerstones of their merging of SD and EC ideas are the following:

- greater emphasis on theory and data than expert opinion and intuition as informational basis
- more nonobservables than usually employed in EC
- preference for nonlinearities in variables because of reluctance against SD table functions
- preference for a recursive causal ordering as in SD models
- preference for a discrete rather than quasi-continuous model, especially because of
- a plea for least-squares estimation of parameters
- preference for EC validation strategies.

One-Sided Convergence With Tendency Towards Equivalence. Zwicker's above mentioned FOLR-modeling concept ([28] pp. 480-521) modifies CSD in four central aspects:

- substitution of the premise of infinitesimal time intervals by the discrete time hypothesis (DT = 1)
- incorporation of finite-distributed lags because of the principle of unconstrained hypothesis formulation
- suspension of the closed boundary concept and allowance for exogenous variables
- a plea for statistical parameter estimation and evaluation.

As all proposals of modified SD (or EC) methodologies FOLR raises the question what remains of the "hard core" of the original approach. Zwicker holds that the two retained elements of CSD - a revised level-rate concept and the feedback concept - are the most fruitful parts. He characterizes them as heuristically powerful procedures for hypothesis generation, guiding the modeling process up to the stage of comparative causal diagrams. It should be recognized, though, that FOLR does not go beyond this rather modest heuristic view of the level-rate and the feedback concept and does neither require a strict alternation of levels and rates nor a feedback of every endogenous variable without exception.

Facing these major shifts from CSD to the FOLR-variant a second question has to be answered: are there still any differences between FOLR and EC modeling? The only key distinction seems to be the recursiveness of FOLR-models. This justifies our assertion that FOLR has a strong tendency towards equivalence with EC.

Coexistence

The perspective of coexistence has been derived from a critical appraisal of SD-EC convergence. "I cannot imagine how the two basic philosophies can be mixed or merged in one model, although the tools that have shaped and been shaped by those philosophies might be exchanged .... Econometrics and system dynamics clearly fit different niches in the modeling policy-making environment. As long as both short-term predictions and long-term perspectives are needed, these two techniques can both be actively pursued, probably with continued mutual hostility, at least until a better competitor comes along" ([1] pp. 235-236). Although we doubt whether the distinction between "borrowings from each other's techniques" and "shifts in world view" is possible or useful, the question, if SD and EC could be merged, leads to the essential point: should both modeling approaches really converge or would it not be preferable to accumulate knowledge on their specific merits and to strive for an active cooperation?

Cooperation

Cooperation does not aim at flattening the differences between EC and SD on a methodological meta-level, but tries to make use of them in the development of specific models.

Rational Choice. This perspective follows straightly from Donella Meadows arguments but does not tend to externalize the choice to the policy-making environment (see also [38] p. 234) It leaves the job of choosing between EC and SD with the model builder. "The rather obvious underlying thought (and conclusion) is that the choice will depend on the ultimate use to which the model will be put, ... It will be argued that the time horizon has significant implications of utilization and epistemology" ([40] p. 27). Although the time horizon is an important aspect of choice (→ Tab. 1, 14.) it is certainly not the only one. Progress along the lines suggested by Dennis Meadows [41] would lead to a deaper understanding of the contribution of the different models features to the achievement of pursued goals.

Modular Linkage. While Chen has argued "that the linkage of models will be successful and meanful only to the extent that the models are epistemologically compatible" [40] the idea gains ground that different parts of a problem might most adequately be addressed by different modeling philosophies (see e.g. [39]). Since we are more and more confronted with a vast amount of already existent models it will become increasingly attractive to link them, in spite of or even because of their different methodological background. Software for such a linkage, like the "Modellbanksystem MBS" of the Gesellschaft für Datenverarbeitung, is in development [42].

Change Of Methodology. During a modeling project it may become evident that the initial choice of a specific modeling approach was wrong or that the model purpose has shifted in the meanwhile so that the choice was correct but is not anymore (unplanned change). Drawing on Zwicker's FOLR concept it can also be argued that SD has a specific heuristic power in the initial phases of model specification while a change to an EC model may be recommendable during the development of a refined model (planned change). A similar view has been presented by Zahn [43].

Cross-Modeling. Finally, cross-modeling should be mentioned as a strategy to gain increased empirical evidence on the factors influencing the rational choice of modeling approaches. While "counter-modeling" ([44] pp. 145-176) holds the methodological meta-assumptions, e.g. the SD approach, constant and changes certain model-specific hypotheses, "cross-modeling" tries to keep the latter as much the same as possible and to formulate models of different types ([41] [45] [46]).

CONCLUSION

Of course, the question raised in the title of this paper does not - as it is the case with all complex and unsolved social science problems - deserve a clear-cut but short-cut answer. It seems very likely, though, that SD will neither displace EC nor be crowded out in the foreseeable future. But if the present state of hostile coexistence will continue or if those, interested in exploring the most promising paths of active cooperation, will be successful, cannot definitely be answered today.

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