IT-RELATED CHALLENGES FOR PROCESS INNOVATION MANAGEMENT

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ABSTRACT

This paper deals with the embarrassing phenomenon of the so-called IT productivity paradox. It starts with presenting relevant findings from previous empirical investigations indicating huge performance differences in the use of information technology (IT) on firm level that may be explained by complementary efforts in organisational renewal and competence formation, while positive productivity effects of IT on the macro level are still hardly measurable. Against this background, methods and results from a new survey on German manufacturing industries are presented that goes beyond previous investigations with respect to richness and representativity of the database and to methodology of the analysis. Based on this analysis and in combination with experiences from case studies, the paper intends to understand the reasons for the questionable economic effects as well as the conditions for improved performance of IT systems implementation and use. From that, it finally derives recommendations for an improved practice in process innovation management on the way to high performance organisations.

1. INTRODUCTION

Information Technology (IT) has widely been conceived as "enabling technology", as a general-purpose technology that in particular could be used as organisational technology enabling new ways of organising high performance work and value creation processes. If so, the widespread application and broad deployment of complex IT infrastructures in organisations should have had marked beneficial economic effects.

According to a growing body of empirical evidence, this is obviously not the case, however, as the literature on the so-called IT productivity paradox indicates (for an overview see Landauer 1995, Brödner et al. 2005). Despite massive and still growing real investments in information technology over roughly forty years now, their positive effects on productivity are, contrary to common belief, unsure or hardly measurable. In many cases the implementation of an IT infrastructure emerges as a barrier rather than a resource to improved economic performance of an organisation. Economic performance indicators often hardly improve despite the high expenses for IT systems implementation. These most embarrassing phenomena – other than in the US widely ignored in the European context – require clarification.

In order to better comprehend what is behind the paradox, the paper starts with summarising relevant findings from recent empirical studies on the subject. While macro level investigations continue to produce alarming results of hardly measurable productivity effects ascribable to IT, firm level investigations, in contrast, point to remarkable performance differences that can be traced back to complementary efforts in reorganising business processes and personnel development in connection with IT systems implementation.

Against this background, we present the methods and results of our own recent survey from the German investment goods producing industries investigating the productivity effects of a wide range of IT systems implementations and new forms of organising work and business processes. With its very detailed data on these issues from a large representative sample of firms in these industries and the complex multiple regression analysis applied, the survey goes beyond previous investigations.

Based on this broad data analysis and on a number of case studies comparing successful with rather challenged ERP systems implementations (taken as examples for complex IT infrastructures), we finally draw some consequences for improving process innovation management practices that appear appropriate to make more productive use of IT systems in organisations.

2. Major Findings from Previous Research

Despite huge and ever growing investments in IT over decades, no noticeable additional productivity effects have been observed on the macro level of the economy. In the USA, for instance, real annual IT investments have increased by more than ten times from a level of 20 Billion USD in 1975 to a level of 220 billion USD in 1990. In the same period of time, productivity in manufacturing has increased by the same small average annual growth rates as before, while productivity in the non-manufacturing sectors has even stagnated (Brynjolfsson 1993).

This has not changed so much since, although productivity in the USA – where investments in IT regularly surpass those in manufacturing technology since 1991 – has significantly increased in the second half of the 1990ies from an average annual growth rate of 1% in the years 1987-1994 up to an average annual growth rate of almost 2,5% in the period between 1995-2000. Many observers have ascribed this productivity growth to IT. However, as the most recent productivity study analyses, this extraordinary productivity leap was solely caused by specific and unique developments in just six sectors: wholesale and retail trades, security and commodity brokers, electronic and electric equipment, industrial machinery and equipment, and telecom services. Surprisingly, these unique developments mainly deal with organisational redesign of the value chains rather than higher efforts in IT system implementations (McKinsey Global Institute 2001).

Since productivity investigations on the macro level are admittedly problematic due to a number of severe measuring problems and to possible compensating effects within a multitude of simultaneous changes, the focus of interest in studying the paradox has switched to the micro level of firm performance. Empirical evidence from firm level investigations on the economic effects of IT systems implementation in large US firms indicates a huge variance in the productivity effects of the systems' use. Some firms are able to achieve four times higher performance with equal IT expenses as compared to other, less successful companies (Brynjolfsson & Hitt 2000). Data analysis refers to relevant context variables such as organisational decentralisation measures or competence development efforts for explaining the variance. In particular, a number of recent firm level investigations (Brynjolfsson 2003, Bresnahan, Brynjolfsson & Hitt 2002, OECD 2004) indicate a relevant impact of organisational change and personnel development measures as most important context variables to understand the different effects IT investments have on productivity.

Firm level investigations have indeed produced a number of remarkable results. Besides a great number of case studies, econometric analysis of data from ca. 400 big US companies (Brynjolfsson & Hitt 2000) points out that

- IT systems may improve a firm's economic performance, if and only if their implementation goes hand in hand with decentralisation, object-oriented reorganisation of work and investment in human capital,
- „intangible assets", e.g. collective action competence, strongly influence the benefit of IT systems,
- firms decentralising their organisational structures achieve higher productivity in using IT systems than those who invest in IT only,
- expenses for organisational renewal and training are a multiple of expenses for hard- and software, e.g. four times higher in case of implementing ERP systems**.**

Against this background, we want to shed more light on the nature of the relationship between IT implementation and labour productivity by simultaneously controlling a great number of possible intervening context variables. Previous studies so far have focused on IT investment and IT capital data as paramount indicators for IT systems implementation and use. These data may not, however, sufficiently reflect the real efforts, since they normally comprise of hardware and systems software expenditures only, while necessary application software, organisational adjustments and learning efforts are not taken into account.

In contrast, our data set allows for drawing a much more detailed and differentiated picture of the extent to which IT is implemented and used in the establishments and to which extent they have undergone organisational changes. The data set thus contains a wide spectrum of specific IT application systems that might be used in manufacturing and not only records whether they are in use or not, but also catches the degree to which its maximum potential use is exploited in an establishment. Similarly, a wide spectrum of organisational changes is included. Thus, the real implementation and use intensity of specific IT application systems as well as the organisational context in which they are applied can be more adequately depicted at the same time.

3. Use of IT in the German Manufacturing Industry

3.1 Design of Investigation and Methodology

According to conventional wisdom and common belief that the use of IT systems will raise productivity, we assume:

H0: *With increasing use of IT in an organisation its productivity increases.*

As already indicated in the review of previous investigations, some findings suggest that implementing IT systems as such may not directly increase productivity. Rather they may require complementary efforts in reorganising work and business processes as well as in training. IT is often seen as an indispensable enabler of new decentralised work organisation while others emphasize that IT could only be exploited to its full potential, if simultaneously corresponding work and business processes are appropriately being reorganised. Whatever the direction is, high productivity would be observed with organisations using both IT and new forms of organisation. We therefore assume

H1: *The more an organisation uses IT as well as new forms of organisation at the same time the higher is its productivity.*

Accordingly, we should disprove: *There is no correlation between a simultaneous use of IT and new forms of organisation and the productivity of an organisation.*

3.1.1 DATA SOURCE

For our analysis we use data from the *Manufacturing Innovation Survey* 2001 by the Fraunhofer Institute for Systems and Innovation Research (ISI). The mail survey investigates the use of new information and manufacturing technologies, the adoption of innovative organisational schemes and managerial practices, company and manufacturing characteristics as well as different performance indicators. The establishments participating in this survey are selected from the parent sample of all German establishments with 20 and more employees of core sectors of the manufacturing industries. The sample covers information for 1.630 German establishments collected in autumn 2001 and referring to economic data for the year 2000 (for more details see Lay, Maloca & Wallmeier 2002).

As the survey covers process industries (chemical, pharmaceutical, and plastics industries) as well as investment goods manufacturing (mechanical and electrical engineering industries) two partly differing questionnaires are used in order to adequately represent the differences in the (technical) manufacturing processes. We therefore restrict our analyses to the investment goods industries (NACE groups 28 to 35[1]). Thus, we can refer to a bigger selection of indicators for the use of IT and new organisational schemes collected identically. At the same time, we limit and control the diversity of manufacturing processes with principally deviating productivity while accepting a certain limitation in the generalisation of the results.

The sample then consists of 1.258 establishments. As this means a response rate of about 11 percent the question of possible biases in the database arises. The sectional structure of the investment goods industries in Germany is very well reflected, as is the geographical distribution of the establishments with respect to the German Federal States. However, there is a slight over-representation of bigger establishments and, accordingly a decreasing participation rate of smaller firms (which is quite common in written surveys).

As a particular advantage of the data set, the surveyed establishments have not only been asked for the use of several computer based information and manufacturing technologies and of numerous new organisational schemes on a yes or no basis. Rather, the date of implementation and an estimation of the extent to which the company-specific potential use of a technology or organisational scheme is exploited have been asked for. The potential is defined as the share of actual use of the technology or organisational scheme compared to the most advanced usage conceivable within the establishment. Thus, the data allow constructing indexes that take account of the breadth und depth of use in a company while at the same time mirroring the length of experience. Beside the available indicators related to IT use and organisational practices, the survey offers a direct measure of (labour) productivity on establishment level and a number of items to control for intervening variables expected to influence productivity (cf. section 4.2).

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[1] Manufacture of fabricated metal products, manufacture of machinery and equipment, manufacture of office machinery and computers, manufacture of electrical machinery and apparatus, manufacture of radio, television and communication equipment and apparatus, manufacture of medical, precision and optical instruments, watches and clocks, manufacture of motor vehicles, trailers and semi-trailers, and manufacture of other transport equipment.

3.1.2 *OPERATIONALISATION*

In order to test the above hypothesis, the implementation and use of IT and of new forms of work and business process organisation has to be operationalised on the basis of the available data and the underlying theoretical approach.

Information technology has, in contrast to the previously dominating perspective of automating knowledge work, recently been more adequately seen as a general-purpose technology providing a digital information infrastructure for manipulating, storing, retrieving, and transferring data and, thus, enabling new ways of doing business and organising work. Despite its general data processing nature, IT has to provide, however, application-specific and user-centred functions in order to become effective, i.e. to be useful and usable. When implementing IT application systems, firms do not just plug in computers or telecommunication equipment and achieve improved process efficiency or product quality. Rather they need to go through a process of reorganising work and business processes in which the application system will be embedded. The functional properties of IT application systems, therefore, determine, together with the organisational procedures they are embedded in, the effects they have on work and business performance (Brödner 2005, Brynjolfsson & Hitt 1998).

That is why we consider it more appropriate to look at the extent to which specific IT application systems are implemented and used rather than the general IT expenses as an indicator for the intensity of IT use in firms. Of the 27 technologies covered in the questionnaire we therefore selected those IT based systems that already show a significant diffusion (indicating that they are not "exotic" or "young" with uncertain productivity impact) and which more or less directly aim at the rationalisation of work processes on the basis of information technology (fig. 1 left column).

IT Index		Organisation Index	
ERP Modules	58	Product-oriented Segmentation	54
CAD/CAM: Geometric Data Transfer	44	Decetralised Planning and Control	36
CAD/ERP: Order Data Transfer	38	Balanced Scorecard	10
Electronic Procurement	41	Regular Individual Consultation	67
Order Data Exchange in Supply Chain	14	Quality Circles	52
PDM Systems	23	Continuous Improvement Processes	65
Simulation Software for Design	8	EFQM Quality Management	17
Exchange of Product Data	56	Simultaneous Engineering	37
Teleservice	47	Cross-departmental Project Teams	50
CNC Machining Centres	59	Segmentation of Production	51
Automated Industrial Handling Systems	26	Integration of Tasks	60
Automated Transport Systems	15	Zero-buffer Production (Kanban)	16
Automated Assembly Stations	18	Group Work in Production	64

Note: The numbers indicate the share of establishments in % using the respective technology or organisational scheme

Figure 1: Components of the technology and organisation index

For catching organisational innovation we take a similar approach. A wide spectrum of new managerial and organisational schemes changing the way manufacturing enterprises operate is considered as basis for our index. These innovative organisational schemes should primarily aim at improved processes and more effective use of human labour rather than other goals like quality or better environmental performance. Again, the 13 innovative organisational schemes were selected from a total of 25 organisational schemes covered in the questionnaire. For selection, a significant diffusion level and a relevant change in work processes were required connected with the principal expectation of potentially positive productivity effects (fig. 1 right column).

For building the indexes for the use of information technology (TI) and for new forms of organisation (OI) the same procedures are applied. Each index is a combined measure of the breadth and the depth of use[2]. It reflects the number of IT application systems and organisational schemes implemented as well as the extent to which an anticipated optimum level for the particular establishment has been achieved. It thus depicts an average use of the total potential for the particular establishment across all IT systems and organisational forms included in the index. Moreover, only those implementations are taken into account that took place before the year 2000 and for which labour productivity data are reported. This should ensure that possible productivity effects are not weakened due to insufficient settling time. Thus, the highest possible index value of 100 would stand for a use of all 13 technologies (or organisational schemes) and the full exploitation of their company-specific potential, e.g. complete possible diffusion within the establishment. The lowest value of 0 would mean that none of the technologies (or organisational schemes) is used.

These indexes have the advantage that they take account of internal diffusion respectively intensity of use and that they do not impinge a normative measure (apart from the selection of technologies and organisational schemes). However, behind the same index value there may be very distinct application patterns of IT and new organisational schemes depending on the framework conditions and strategies in the particular establishment. They, thus, reflect to some extent the specific requirements a firm has for using IT systems and new organisational forms.

4. FINDINGS

The presentation of our findings has two sections: In a first part we present the results of the analysis where we have tested if there are correlations between the advanced implementation of manufacturing technologies respectively innovative organisational concepts on one hand and productivity effects on the other. In a second part we describe the findings of a multiple regression analysis based on different models explaining differences in productivity by a set of variables that, beyond technological and organisational innovations, may possibly influence productivity performance.

4.1 RESULTS OF BIVARIATE TESTS

Bivariate analysis reveals a positive correlation between productivity and both the organisation and technology index. Table 1 shows Pearson's correlation coefficients as the degree to which productivity and the indexes are related. The highly significant ($p<.001$) positive correlation indicates that productivity is not independent of the use of IT systems and innovative organisational schemes. This result suggests that firms can increase their productivity by implementing advanced computer-based manufacturing technologies. In this sense, the IT productivity paradox is not supported by our data.

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2 The index value I_k is calculated for each establishment k according to $I_k = 1/n \sum P_{ik}$, where P_{ik} numeralises the extent to which establishment k exploits its deployment potential for index component i (n is 13 here).

	Productivity		
	N	Pearson's Correlation Coeff.	one side significance
IT Index (TI)	628	.191	.000
Organisation Index (OI)	545	.193	.000

Table 1: Correlation between productivity and IT and organisation indexes

The correlation coefficient between productivity and organisational innovation shows the same dependency. The correlation coefficient of .193 ($p<0.001$) indicates that establishments can reach a higher productivity by reorganising their work and business processes. Organisational innovations seem to be a valuable source of productivity, just as technology is. This finding based on bivariate analysis corresponds to the positive impact new forms of work and process organisation have on labour productivity and competitiveness reported in the literature (cf. e.g. Bauer 2003, Zwick 2003).

4.2 RESULTS OF MULTIPLE REGRESSION ANALYSIS

The bivariate analysis of correlations between productivity as dependent variable and technology implementation and organisational innovation as independent variables does not, however, allow a deeper insight into the complex system of driving forces for increased productivity. As other variables that may also influence productivity are neglected, a detected bivariate correlation could very well result from the influence of a hidden independent factor stimulating or hampering productivity. In order to analyse the impact of technological and organisational innovation together with other independent variables on labour productivity (value added per employee), a multiple regression analysis has been carried out including the following variables.

Firm size (number of employees) is a criterion that indicates to what extent an establishment can realise scale effects in producing goods. Therefore, it is safe to assume that increasing numbers of employees can positively influence productivity. An increase in productivity can be assumed, too, if the share of qualified workers is high. A qualified workforce is regarded as a prerequisite of a productive production system.

The core competence debate has highlighted the fact that enterprises may achieve productivity above average when concentrating on those specific tasks they do better than others. Outsourcing (measured as 1 minus value added per sales) was discovered as an important source to improve productivity and competitiveness. Furthermore, a big export share on overall sales could also be a stimulus for increasing productivity. The competition on global markets is regarded as driving force for exhausting all resources in order to gain productivity. The same applies to suppliers of the automotive industry, where the oligopolistic demand side of the market forces supply firms to constantly reduce prices and costs. Last but not least the extent to which an establishment utilises its capacities should have a positive impact on productivity. If due to lacking orders there is a significant share of equipment standing still the productivity obviously is doomed to go down.

In contrast, there are some factors that are expected to have a negative impact on productivity. First, the share of produced goods not accepted by quality checks has to be mentioned. If the reworking quota is high, productivity will most probably suffer.

Productivity might be low furthermore with companies having introduced new products into the market. It goes without saying that production processes for innovative products cannot be that much elaborated as for those goods that have been produced for several years and where all weaknesses have already been detected and weeded out. A third factor for relatively low productivity might be a high share of manual manufacturing tasks due to product characteristics (measured by the share of manufacturing staff in total employment).

Finally, a factor specific for the German situation has to be introduced, as our model is based on a German database. After political unification, the establishments in former East Germany are, in terms of productivity, still far behind the establishments in former West Germany. The reasons have been investigated several times; they are mainly rooted in factors such as inability to sell for normal market prices or insufficient technology management competences.

We estimate the productivity effects of technological and organisational innovations by the following function:

$$\ln Y = \alpha\, TI + \beta\, OI + \delta\, X + \varepsilon.$$

The equation describes a model where Y is productivity, TI is the technology index, OI denotes the organisational index and X represents the vector of control variables. The parameters α, β and δ are the regression coefficients to be estimated and ε is the normal distributed error term with expected value zero and variance σ^2. The model takes account of the fact that the correlation of productivity with the independent variables is not linear. Rather a logarithmic function seems appropriate assuming a diminishing marginal utility of the impact of the independent variables on productivity.

In a first step (model 1 in table 2) of the multiple regression analysis, we have tested if there is an impact of organisational innovation on productivity and how strong this influence is compared to the other variables mentioned above. The R^2 value indicates that this model explains 35 percent of the variation of the dependent variable. The impact organisational innovation (OI) has on productivity is statistically significant (coeff. .081, $p<0.10$), however very small as compared to other independent variables such as "outsourcing" (coeff. -.333, $p<0.001$), "firm size" (coeff. .302, $p<0.001$), "share of manufacturing staff" (coeff. -.156, $p<0.001$), "qualification level" (coeff. .134, $p<0.001$), "capacity utilisation" (coeff. .123, $p<0.001$), "export share" (coeff. .119, $p<0.05$) and "share of new products" (coeff. -.084, $p<0.05$); all these factors explain the variance of productivity among establishments to a much greater extent than organisational innovation does. This could be the reason for the difficulties in some empirical attempts to prove the impact of organisational innovation on productivity.

In a second regression model (model 2 in table 2) we have replaced the organisational innovation variable by the technical innovation variable. The R^2 value of this regression model indicates that 32 per cent of the variance of the dependent variable "productivity" can be explained. The regression results reveal that the estimated coefficients for the variables tested in both models maintain their positive respectively negative signs. IT systems deployment obviously has a positive impact on productivity (coeff. .140, $p<0.05$). This impact is again not the dominant one, however.

A third model simultaneously analyses technological and organisational innovation in their impact on productivity as compared to the other independent variables. Based on 374 observations, this model explains 35 per cent of the total variance of the dependent variable ($R^2 = .35$). Obviously, IT systems implementation retains its positive impact on productivity (coeff. .159, $p<0.05$) while the coefficient for organisational innovation is no longer statistically significant (coeff. .002, p>0.10). It may thus very well be the case that organisational innovation can show an impact on productivity only in combination with IT systems. We saw that there is a strong correlation between IT systems implementation and new organisational conceptions. In a multiple regression model the whole impact of these kinds of techno-organisational innovations are attributed to the technological variable, however, obviously because of the fact that organisational innovations can develop their positive impact on productivity only if mediated by IT.

	Model 1		Model 2		Model 3		Model 4	
	Coeff.	t	Coeff.	t	Coeff.	t	Coeff.	t
Outsourcing	-.333	5.14***	-.311	5.02***	-.374	5.45***	-.375	-5.45***
Size	.302	4.47***	.316	4.83***	.312	4.29***	.316	4.25***
East Germany	-.345	-7.83***	-.234	-5.49***	-.297	-6.29***	-.301	-6.36***
Manufact. staff	-.156	-3.03***	-.186	-3.74***	-.174	-3.18**	-.172	-3.14***
TI	-	-	.140	3.14**	.159	2.89**	.164	2.97***
Qualification	.134	2.62***	.160	3.16**	.136	2.51**	.134	2.47**
Export	.119	2.40**	.143	3.07**	.122	2.35**	.188	2.27**
New products	-.084	-1.95**	-.119	-2.83**	-.100	-2.19**	-.105	-2.29**
Cap. utilisation	.123	2.95***	.090	2.23**	.100	2.25**	.100	2.26**
Rework	-.031	-0.78	-.036	-0.91	-.044	-1.02	-.045	-1.04
Automot. supply	.032	0.72	.040	0.92	.038	0.80	.039	0.82
OI	.081	1.77*	-	-	.002	0.04	.000	-0.00
Interaction TI/OI	-	-	-	-	-	-	-.007	-0.14
Constant	1.533	16.63***	1.556	18.28**	1.549	16.84**	1.820	22.14***
8 Sector dummies and production structure	yes		yes		yes		yes	
Observations	417		471		374		374	
corr. R^2	.35		.32		.35		.35	
F-test	11.708***		11.510***		10.158***		10.068***	

Notes: The interaction term is defined as: IT index times index of organisational schemes
*** Significance level <.01 ** Significance level <.05 * Significance level <.10.

Table 2: Multple regression results

Model 4 in table 2 goes a step further as it tries to consider such an interaction mechanism. However, the results resemble those of model 3. The interaction of technologies and organisational innovation as they are measured by our indexes does not prove to have a significant impact on productivity.

Additionally, the implementation of new organisational schemes may require careful consideration of mutual compatibility conditions rather than following a "the more the better" strategy. Such an integrative techno-organisational modernisation strategy may – considering the many myths and fashions dominating the debate in the past – not easily be achieved by the majority of companies. Actually, organisational innovation may not primarily be targeted towards an increase in productivity. New forms of organisation often attempt to improve performance in terms of flexibility and quality while productivity is hoped to stay at least unchanged. The regression result of a positive coefficient for the organisational variable in model 1 may be regarded as a hint that the implementation of innovative organisational schemes directed towards flexibility and quality is no hampering factor for productivity.

Technological process innovation using IT on the other hand does not seem to face a comparable compatibility problem and may more easily be used efficiently. Not least, it is worth mentioning that the increase of labour productivity is the ultimate purpose of implementing IT systems and may well be (and often is) achieved at high costs in other respects such as high implementation and capital cost or reduced flexibility.

5. Consequences for Improving Process Innovation Management

Considering these results together with findings from previous firm level investigations (cf. section 2), we can conclude: IT systems implementation does have a significant – yet weak – positive impact on productivity. However, in order to put the systems to effective use at their full potential, it is important that they are appropriately embedded in the work and business processes they are designed for. This is not an easy task, of course, since a number of conditions and procedural requirements must be regarded.

This may be highlighted by our own case study research on the implementation and use of ERP systems in German manufacturing enterprises. Seven out of ten companies follow a purely technology-centred strategy focused on system functionality combined with a top-down system implementation procedure. This produces highly detrimental consequences for economic performance, though: IT implementation projects regularly burst time and cost budgets to a considerable extent, while relevant performance indicators such as productivity, lead-time and in-process inventories are hardly improved, despite the extremely high expenses. The implementation process mainly concentrates on requirements engineering and design issues without end user participation, and efforts for appropriation and training are low. As a consequence, many functions of the system are not or poorly used, necessary knowledge about the integration in underlying business processes, their working principles and conditions is lacking, and large amounts of deficient or redundant data are being produced in use.

A small minority of firms only follows a more sophisticated and economically much more beneficial strategy starting with organisational redesign of their business processes and object-oriented reorganisation of work with strong customer focus. Regarding the new organisational structures, they simultaneously implement the functionally adapted IT system as a supporting tool and medium for cooperation. Accordingly, end users are involved in these processes of organisational design and system implementation from the beginning, while collective learning processes for appropriating and enacting the new ways of working are systematically organised (Maucher 1998, 2001).

Similar findings have also been reported from case studies by other researchers (Davenport 1998, Farrell 2003). They obviously point to what is behind the paradox: How organisations understand and deal with computer artifacts either as means to automate existing work or as enabling and supportive media for creating and enacting an improved organisational practice decides about the economic benefits that can be gained. Making effective and beneficial use of computer artifacts is obviously more than just implementing a functionally appropriate IT system.

From a theoretical perspective, IT systems are “semiotic machines” that, in contrast to conventional technical artifacts, embody formalised routines derived from sign processes of social interaction in the underlying knowledge work. While manipulating signs by formal instructions, they become part of the social structure of the work processes they are designed to support. IT systems thus turn out to be media for organising work ("software is orgware", Brödner 2005).

A paramount consequence of the semiotic nature of computer artifacts and their embeddedness in sign processes of social interaction is the indispensable fact of "double hermeneutics" that observations of social systems like organisations do change their own object of observation. Hence, the object of observation, the social system, is reflexive in the sense that the explicit knowledge gained about the system – as well as the IT artifacts derived from that knowledge – become part of the system's resources and rules being themselves changed by this. Formalisation and algorithmisation exactly are such events of observation that change the object of observation. Sign processes observed and modelled in this way, therefore, are being changed by exactly these activities: The object of modelling undergoes change by the process of modelling itself – a fact that has been almost neglected so far. A number of procedural consequences can be concluded from these theoretical considerations.

First, frequent changes of functional requirements during system design and implementation are inevitable. Project management must cope with this inescapable fact and organise design and implementation processes in a reflexive or evolutionary way with iteratively revised and improved versions of the system or its modules. This requires sound procedures that combine aspects of modular design, formative evaluation and collective learning with constrained range in order to confine the risks. Moreover, project management must conceive and organise the joined evolutionary design, implementation and appropriation efforts as integral part of organisational development.

Second, due to the self-referential nature of IT systems implementation, the effects produced are not solely dependent on the implemented system functionality, but are a result of how they have been socially embedded and enacted for practical use. System quality can, therefore, only be evaluated in the context of practical use.

Third, it is indispensable to involve end users in design and implementation of both the technical and the organisational features of the new work process from the beginning. As designers normally have little understanding of the working tasks and procedures and users have only little knowledge about the options IT has to offer for organisational redesign, both main actors in the design and implementation process must cooperate. In order to overcome their symmetrical ignorance, they are compelled to develop a shared understanding of the underlying work processes and frame conditions.

Forth, all actors involved must realise the fact that implementation and use of IT systems have strong impact on the balance of organisational flexibility and rigidity. The purpose of organisations is to enable efficient collective acting by reducing contingency and confining the space of communication by rules, routines and formal procedures. And as IT systems, by definition, operate on the basis of completely determined procedures in form of algorithms, they appear as a most appropriate organisational medium. However, as they in turn impose rigid action requirements on the users working with them, they may overly constrain the necessary flexibility in action that is needed to cope with uncertainties and surprises in the organisation's environment.

Fifth, as the development of IT systems so far has been predominantly concentrated on design according to functional requirements, the reverse process of appropriation and enactment for effective use has been almost neglected. However, the skill to make sense of the artifacts, to find adequate interpretations for accomplishing the working tasks is at least of equal importance and requires creative acting as well. Project management, therefore, must systematically organise collective learning efforts necessary for the artifacts' effective appropriation and enactment, while regarding that they are much more expensive than design.

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