technische universität
dortmund

Hartmut Hirsch-Kreinsen

Industry 4.0 - A Path-Dependent Innovation

Soziologisches Arbeitspapier Nr. 56/2019

Herausgeber

Prof. Dr. H. Hirsch-Kreinsen

Prof. Dr. J. Weyer

Prof. Dr. M. Wilkesmann

Industry 4.0 - A Path-Dependent Innovation

Hartmut Hirsch-Kreinsen

Arbeitspapier Nr. 56 (Januar 2019)

ISSN 1612-5355

Herausgeber:

Prof. Dr. Hartmut Hirsch-Kreinsen

Prof. Dr. Maximiliane Wilkesmann

Professur Wirtschafts- und Industriesoziologie

www.wiwi@tu-dortmund.de/IS

Prof. Dr. Johannes Weyer

Fachgebiet Techniksoziologie

johannes.weyer@tu-dortmund.de

www.wiwi.tu-dortmund.de/TS

Fakultät Wirtschaftswissenschaften

Technische Universität Dortmund

D-44221 Dortmund

Ansprechpartnerin:

Britta Tusk, e-mail: wis.wiwi@tu-dortmund.de

Die Soziologischen Arbeitspapiere erscheinen in loser Folge. Mit ihnen werden Aufsätze (oft als Preprint), sowie Projektberichte und Vorträge publiziert. Die Arbeitspapiere sind daher nicht unbedingt endgültig abgeschlossene wissenschaftliche Beiträge. Sie unterliegen jedoch in jedem Fall einem internen Verfahren der Qualitätskontrolle. Die Reihe hat das Ziel, der Fachöffentlichkeit soziologische Arbeiten aus der Wirtschafts- und Sozialwissenschaftlichen Fakultät der Technischen Universität Dortmund vorzustellen. Anregungen und kritische Kommentare sind nicht nur willkommen, sondern ausdrücklich erwünscht.

Abstract

Starting point of this paper is the prevailing view in the digitization discourse that there is currently a pronounced technology push with disruptive consequences for work. The article argues, however, that disruptive and structural change is by no means to be found or expected in all economic sectors and working segments. The thesis of this paper is that the digitization of work in the sector of industrial production is tied to a markedly path-dependent process of technological innovation and transformation of work. It is shown empirically that path dependency can be identified by incremental digitization measures in most companies and a related structurally conservative change in work. To explain these findings, conceptual considerations of organizational path dependence are invoked which emphasize particularly the mechanism of self-reinforcing increasing returns. However, technological and organizational path-dependency does not exclude the possibility of disruptive change. Therefore, the empirical and theoretical preconditions for longer-term disruptive change in work processes are discussed in conclusion.

Inhalt

1. Introduction[1]

The paper asks about the patterns of digital innovation in industrial production and its consequences for organization and work. The widespread thesis is that digital technologies are opening completely new and unknown technology application potentials with no less than *disruptive* technological, social, and economic consequences and it opens up new possibilities for future economic growth (Avant, 2014; The Economist, 2017). In this view, a new era is recognizable that in the international debate is variously called the "second machine age" (Brynjolfsson and McAfee, 2014; McAffee and Brynjolfsson, 2017), the "third industrial revolution" (Rifkin, 2010) or, in the German-speaking countries, the "fourth industrial revolution" – respectively, "Industry 4.0" (e.g. Forschungsunion and acatech, 2013; Hirsch-Kreinsen, 2016; Garibaldo and Rebecci, 2018). Without question, this debate currently has all the characteristics of "hype": spectacular changes and prospects are predicted and, in professional circles, politics and far beyond, no other issue is so often attributed such an important role in the visions of future social and economic development. With reference to sociological innovation research Industry 4.0 can also be understood as a "promising technology", based on the premise that advances in digital technologies will bring about new and positive technological, economic and social prospects (Hirsch-Kreinsen, 2016a).

Indeed, the thesis of a foreseeable disruptive development in technological, social and economic structures cannot be fundamentally refuted. Without question, in a whole range of economic sectors, a sustained process of far-reaching structural changes is occurring through digitization. For example, from the end of the 1990s these were sectors where production, sales and communication are directly based on immaterial transactions, as well as on the use of large amounts of data. To be mentioned here are service sectors such as music production and distribution, publishing and press, or also financial services, whose digitization has caused far-reaching changes in company and sectoral structures (Zuboff, 2010; McAfee and Brynjolfsson, 2017). In particular, also in consumer goods, through use of digital platforms as coordinating media, far-reaching transformations are taking place that have been leading to a new quality of business-customer relations, business models and related models of work. Also significant here is the accelerating spread of new forms of unbound work through digital networks and platforms, also known as "crowdwork" or "gig work". Empirically this development

---

[1] *This paper is a revised version of a German-language text first published under the title "Die Pfadabhängigkeit digitalisierter Industriearbeit" (Hirsch-Kreinsen, 2018).*

until now has been located mainly in sectors like IT and software and in a number of service fields (e.g. Leimeister and Zogaj 2013; Staab, 2016; Schmidt, 2017).

However disruptive structure change is by no means found in all economic sectors and segments of work processes. Against all expectations, such as especially expressed in the German Industry 4.0-discourse, evidence shows that industrial production in particular has been characterized by only rather moderate innovation patterns and transformative tendencies in recent years. Therefore in the following it will be argued that with digitization, resp. Industry 4.0 are not generally associated with disruptive consequences, but rather, that digitalization in industrial production until now has involved a pronounced *path-dependent transformation* work processes. As shown in the following, this thesis is based on a multitude of empirical evidence as well as conceptual considerations from research in the sociology of organizations about path-dependencies in organizational change.

The paper's argumentation comprises the following steps: first, the empirical basis and the conceptual framework are introduced (sections 2, 3). Second, this study's empirical findings are summarized (section 4), and third, the question is posed of what preconditions are necessary for the emergence of long-term tendencies of disruptive change in industrial production (section 5).

2. Methods and empirical basis

The empirical basis of the following presentation comprises two complementary methodological approaches:

- First, the argumentation is based on the results of ongoing analyses of the relevant literature as well as of the public and scientific research discourses on the patterns and social effects of digital innovations. Here the results of above all the statistical quantitative analyses are summarized.

- Second, the approach draws on qualitative results of case studies of manufacturing companies in Germany that have engaged with Industry 4.0 and thereby at least in part already introduced new digital systems.

The company case studies were and continue to be conducted at TU Dortmund University within the framework of two empirical projects in basic research, as well as in the context of three application-oriented research projects.[2] The company sample used here comprises 23 German companies in machine building, electrotechnical equipment, the furniture industry and logistics. These are mostly SMEs with up to 500 employees (9 firms); five firms with up to 1000 workers; and nine larger companies that, at the study locations, in part employ more than 1000 persons. In these plants the introduction of the most various digital technology systems was investigated. These were, for example: so called lightweight handling robots, autonomous guided vehicles (AGV), planning and scheduling systems like Enterprise-Resource-Planning systems (ERP), radio-frequency identification (RFID) product coding, various kinds of shopfloor information systems, as well as networked transport and logistics systems.

The case studies were of varying intensity: on the one hand in some of the firms they were limited to one or two interviews with company management and/or works council and union representatives. On the other hand at other companies the analysis had an intensive character, comprising a series of interviews with management representatives and works council deputies as well as extensive and in part repeated plant tours.

Since the research projects are in part still being carried out, this paper summarizes preliminary results. That is, the present study's results have not (yet) been systematically evaluated; rather, they are here selectively used to support and illustrate the theses of this paper. In this way, the following argumentation is part of a "work in progress", and intended to initiate discussion and further research.

3. The concept of path-dependency

With the thesis of path-dependent change in technology and work is taken up a prominent explanatory approach in the social and economic sciences that thematizes the stabilizing effects of organizational and institutional change (e.g. Mayntz, 2003). Path-dependency is understood as a transformative process that above all through positive feedback effects and the avoidance of incalculable risks follows a path largely predetermined by the given organizational structure and personnel-related influences. Certainly the concept of path-dependency requires specification and an analytical relation to a concrete research question in each case, if it is not to remain only a concept with little explanatory character (ibid.). In the case of the

---

[2] *For further information about our current research projects see: http://www.neue-industriearbeit.de/index.php?id=2*

research question discussed here of innovative techno-organizational change at the company level, it is possible to resort to theoretical economic and sociological considerations about relevant mechanisms of path-dependency in organizations (e.g. Beyer 2010; Sydow et al. 2009; 2018).[3] Most important here is the mechanism of *increasing returns* that, in given techno-organizational process structures, induces self-reinforcing effects. Increasing returns are precipitated and caused by more or less frequently occurring "small events", but also by accident. According to the instructive summary of the concept due to *Jürgen Beyer*, this situation is present when the application of a new technology increases the economic advantage of given processes and with that stabilizes their structures and procedures (Beyer, 2010). It is emphazised that such effects can occur especially with new knowledge-based technologies, precisely in the case of the current digitization process, since basically economic limits are considered to hardly exist in the sense of lower advantage effects (Arthur, 1996).

Mechanisms of increasing returns are caused by various effect relationships. For technological change the following can be considered relevant:

- *Technical interrelatedness:* The usefulness of new technologies can be realized fast if these can be integrated into existing technical systems, whereby existing techno-organizational bottlenecks and suboptimal situations can be eliminated.[4]

- *Optimization effects:* The efficiency of established work practices and routines can be in the short term raised through reciprocal effects with the new technologies, and are organizationally stabilized through that. Through these optimization effects, potential risks, uncertainties, and additional costs can be avoided. And, with that the actually or even only supposed pressure of amortization of earlier_investments, which are termed "sunk costs", can be taken into account.[5]

- *Securing complementarity:* This means conserving of the existing functional interdependencies and synergies_of the different technological, organizational, and social elements of a production process. The already established technological routines and related work practices guarantee productivity, smooth running and synergy effects in the given sociotechnical systems of a production process. It is therefore plausible that through techno-

---

[3] *"Mechanism" is understood here as a repeating process that connects certain causes with certain effects, similar to the concept of "effect relationship" (Wirkungszusammenhang) (Mayntz, 2003).*
[4] *See here the mechanism of "technical interrelatedness" in Beyer (2010) resp. David (1986).*
[5] *See here the concept of "quasi-irreversibility of investment" in Beyer (2010) resp. David (1996) and the discussion of the factor of "sunk costs" in Sydow et al. (2009)*

logical innovations, the existing process logic and synergies of production should not be disturbed by the new technologies and expensive compensatory measures and follow-up investment should be avoided.[6]

This differentiation between various mechanisms that lead to increasing returns and overall to a stabilization of given process structures, is certainly of an analytical nature. As to be shown (section 4), they are in reality closely related and lead to probably not only different, but also similar effects.

It should be stressed furthermore that these effect relationships do not at all imply inflexibilities (Beyer 2010): For one thing, these mechanisms do not lead to totally restrictive "lock-in" situations, but rather they signify the corridors within which structural variations and gradual change are possible. The knowledgeable actors involved in the processes — company management representatives, works council delegates and the employees — have choices in regard to the given structures and can therefore vary these within certain limits (Sydow et al., 2009: 695).

Therefore, in the long term view may be expected not only a stability of development, for the aforementioned stability-insuring mechanisms imply also the potential for structural change. In other words: an end to the techno-organizational development path that has been followed is within the realm of the possible (Beyer, 2010). In regard to the analysis of digitization effects and possible disruptive change processes also in the industrial sector, this aspect is of great interest and is therefore taken up in the conclusion of this paper (section 5).

4. Path-dependent change: empirical evidence

As the empirical findings indicate, with the introduction of digital technologies in the industrial sector a break with the evolved techno-organizational and personnel structures is not to be expected. Rather, with the application of new technologies processes are only moderately developed further and continually rationalized. To show this more precisely, this path-dependency can be empirically identified on the following dimensions:

---

[6] *This is to borrow from Sydow et al. (2009: 699) the mechanism they define as "complementary effects"; see also Beyer (2010).*

- First, the digitally based process innovations in most companies proceed predominantly *incrementally,* and are closely bound to the given technological, functional, organizational, and economic conditions in the companies applying digital innovations.

- Second, change in work processes is *structurally conservative.* It shows an often only gradual character and proceeds within the framework of existing organizational structures, without these being broken apart or fundamentally changed. At the most, existing work processes, through limited modifications of the forms of work to the demands and possibilities of the new technologies, are changed and continually rationalized within given structural frameworks.

In the sense of the concept of path-dependency these trends can also be considered "small events" causing continuously increasing returns, in as far as the given processes are only stepwise and moderately changed.

4.1 Incremental technological innovation

That digitization in industrial production has up to now proceeded incrementally, can be determined first on the basis of the available statistical data on the spread of digital technologies in German industry. Differently from in the larger "high-end" companies often cited by in the public debate digitization takes place in most companies only step-wise and within limitations (e.g. Arntz, 2016; BMWI, 2016; Icks et al., 2017; Lerch et al., 2017 Schmidt, 2017). According to the present data spread, in manufacturing — by comparison with the ICT sector, finance and insurance providers, knowledge-intensive services and retail — a great hesitancy towards digital technologies is recognizable. In an IAB/ZEW study from 2016 almost half of all manufacturing companies (46.5%) had not yet faced up to the issue of digital technologies, while barely 37% of the surveyed companies had partially applied these technologies (Arntz, 2016: 4). Individually however, the industrial production sector, with regard to the degree of digitization, must be differentiated into various company types. If one aggregates the available research findings from the literature (e.g. Kleinhempel et al., 2015; Pfeiffer et al., 2016; Saam et al., 2016; Icks et al., 2017) and the detailed findings of our own studies (e.g. Wienzek, 2018), there emerges as a first approximation the following picture:

- First, one can speak of a *far-reaching digitization*. These companies apply the new digital technologies systematically and they follow a long-term planned digitization strategy. ZEW data show that up to ca. one-fifth of manufacturing companies can be classified into the pioneer category (Saam et al., 2016). These are mostly technology-intensive, larger companies in machine-building, the auto industry, electrotechnical equipment but also chemical and processing industries. Their process structures are characterized by high complexity as well as high batch production (Lerch et al., 2017). In our study sample around seven companies in machine-building and electrotechnical equipment fit into this category.

- A second company category can be called *selective digitizers*. The findings show that all companies in this category use very basic applications of digital technologies such as new scheduling systems, and internet and cloud computing. A further feature of this type is the stepwise, but limited application of digital technologies. Statistically these companies represent a share of all companies that — varying with the definition used — lies between one-third to just short of one-half. In the present data spread these companies are found in all manufacturing sectors, though SMEs are disproportionally represented (ibid.). In total from the study sample ca. eleven companies, mainly in the logistics area and the metalworking industry, can be classified as in this category.

- A third category can be termed as *skeptical companies,* or *non-users*: these companies are mostly very unsure about what path to digitization could prove advantageous for them. This category also includes companies that are uninterested in digitization applications and very skeptical towards the current debate on Industry 4.0. The central feature of these companies is that the very basic digital technologies such as internet, ERP systems or networked control systems are used in only very rudimentary form often mixed with traditional organizational procedures. These firms often are single-batch or small-batch producers. To go by the available data spread, this company type comprises up to one-third of all the enterprises (ibid.). In our study sample around five companies can be classified as in the "skeptical" category.

As to the reasons for the majority's only limited and incremental application of new digital technologies, the present qualitative findings above all provide relatively clear indications. This situation can be traced to the interaction of two of the above explained mechanisms of path-dependency: one mechanism is the interrelation between the old and the new technologies in the companies. With the addition of new systems existing IT solutions are optimized through updating with new programs, improved networking, an increased data availability and better hardware. As for the other mechanism, unmistakable are resultant optimization effects on existing processes, achieved through partial improvements and the elimination of existing "bottlenecks" such as undependable onward data transfer or absent network capabilities.

These mechanisms of course work differently in dependence on the type of a particular company: in the case of the *far-reaching digitizers*, it is not only a matter of new, improved systems on the shopfloor, but in side-areas too such as logistics or engineering where new systems are also introduced. A typical case is a larger machine-building firm that thanks to a digitally-assisted work-station information system wants not only to consistently reduce, but also completely abolish the existing "flood of paper" in assembly processes. Further points of approach are the networking of the various systems, an optimization of data stocks and information functions in control and management systems, as well as the implementation of self-controlling systems such as modern lightweight robots.

These process innovations are accompanied by product innovations and the stepwise development of new data-supported business models. Explicitly new, structure-changing technology applications such as a platform-based network of customer relations and product users are found in only two of the firms studied. A situation often encountered in machine-building and the electrotechnical industry, and a driving factor is the circumstance that these companies are equally developers and manufacturers of the new technologies themselves, and that through the application in their own production operations they want to be able to demonstrate the functionality and high efficiency of their innovations to potential customers.

By contrast, it is typical of the *selective digitizers* that they mainly realize partial solutions in production, while advanced, e.g. areal- or company-wide applications, are quite rare. An example is the updating of long-installed CAD/CAM networks with the intention of extending their reliability and functionalities through the implementation of new software systems. A middle-sized company of the furniture industry is an example: In this company the introduction of an AGV-system of took place in order to optimize the existing assembly through a faster transport of product components without changing the basic layout of the process. In many other companies existing internal communication and data systems are upgraded, various function areas, particularly production and planning are more closely networked, and planning and control systems further developed. Also is often observable the stepwise introduction of mobile terminal devices such as tablets or also wearables of the most different kinds, with the aim of making a more effective flow of information, eliminating existing information deficits and, in the long term, achieving the "paperless factory".

Finally, in many of the *skeptical companies* small steps toward digitization and the updating of the given process structures can be observed. Quite apparently in these cases there is scarcely digitization or innovation pressure, but rather limited rationalization measures sufficient to meet pressures of cost and competition. An example is the introduction of digitized systems in limited areas as storage and logistics by which the existing processes are supposed to be accelerated and made more reliable. Typical examples of this situation are SMEs in traditional sectors of metal, plastics or food-processing who in traditional processes manufacture mainly relatively simple products for which the extent of automation is limited. Such companies are able to achieve sufficient efficiency of production processes on the basis of relatively low-level technology, and they prefer to avoid what in their view could be the incalculable costs of new digital systems.

4.2 Structurally conservative change of work processes

These incremental digitization steps are accompanied by a structurally conservative change of work processes; that is, the dominant organizational and work-related structures are largely retained despite the implementation of new digital technologies. At most they are changed by marginal modifications to work procedures in order to accommodate the new technologies and then they are continually adjusted. On the basis of findings available up to now, this situation can be traced to the above-mentioned mechanisms that bring increasing returns and self-reinforcement of the given structures: namely the effects of an ongoing optimization process, in part in small steps, as well as the necessity of assuring the complementarity of the different sociotechnical process functions and elements. As can be shown, the majority of companies therefore retain well-established work practices and given job qualifications.

Process optimization

An optimization of existing processes without further-going structural changes is found in many companies that can be considered *selective digitizers*, and in companies *skeptical of digitization*. As already mentioned, process optimization in these cases takes place — for example through the introduction of mobile data devices to improve the steering of orders, the extension of networks between indirect planning areas and the shopfloor with the further development of CAD/CAM systems, avoiding thereby "media gaps", or the introduction of a AGV system coupled with IT-supported systems of work assignment. All these process innovations are aimed at an optimization acceleration of the work process. Work processes are optimized when work instructions are made clearer and less prone to error, material delivery becomes less vulnerable to disturbance, or machine control programs more precise. The consequences for processes are lower levels of disturbance, reduced need for worker decision-making, and the tendency towards progressive standardization and simplification of procedures. In no case however does this entail structure gaps in the scope of activities, qualification demands or the use of personnel. Rather, the specific work processes become more efficient and the previously often observable worker stress caused by disturbances and error-prone information is reduced observably, at least in part.

As an example of a process optimization it can referred to the introduction of mobile assistance systems, e.g. tablets and Apple Watches by a small metalworking firm that can be counted among the selective digitizers. The activities of production workers changed as follows: In the past they had to call logistics in order to get a new supply of necessary parts. This didn't always succeed well however, when the logistics people were on their break, or the telephone was busy or an order was simply forgotten. Now the logistics workers have an Apple Watch, and the shopfloor personal makes the orders via iPad. Logistics now has thereby all orders in the correct sequence on their watches. The shopfloor as well as logistics like the new solution, which significantly prevents disturbance situations and the attendant stress.

A marginal advancement of work processes can be illustrated by a smaller, rather *digitization-skeptical logistics company* that provides automobile producers' replacement parts deliveries. The work processes of the company were previously characterized as centered around an unwieldy "piles of paperwork". The reform of this foresaw the introduction of a digital information system in two steps. In the first, the forklift drivers were to be supported by industrial PCs mounted in the forklift, on which the next five to ten orders were to be displayed and individually confirmed and sequentially carried out by the driver. Recognizably a certain freedom of decision enjoyed previously by the forklift drivers will be thereby largely eliminated. The packing workers on the other hand will now be supported by the tablets installed at their workplaces. They can electronically activate or de-activate orders as well as receive or request any special instructions for packing an order.

Assuring complementarity

The structurally conservative change in work described can be also explained by the necessity of assuring the complementarity of the various sociotechnical process elements and functions. To do this the majority of the companies, largely independent of the digitization type, resort to practiced modes of work and existing worker qualifications. Concretely, this mechanism is graspable in the more or less ongoing adjustment between the digitally formalized virtual process replicas and the work specifications resulting from them on the one hand, and the often not exactly calculable actual physical and social process execution on the other hand. This is a phenomenon that social science labor research has already long pointed out (e.g. Funken/Schulz-Schaeffer, 2008). On this view, many automation processes function only when workers apply ordinary everyday creativity and improvisation skills in order to deal with the quirks and disturbances occurring during automation (e.g. Heidenreich et al., 2009; Büchner et al., 2017).

As the available findings also show, the preconditions for this are specialist knowledge, accumulated experience and the motivation of the employees to engage in the ongoing process of managing the new technological demands. One interviewed expert formulated this situation explicitly as when the worker always knows "a thousand times better" than the boss how a production process actually functions. This suggests therefore the broad retention of practiced forms of personnel deployment, the qualification structure, and the work organization, in order to avoid unnecessary risks in the application of new technologies. Thus remain, in the case of the above-described digitalized control of logistics processes in a smaller logistics firm (of the selective digitizer type), spaces for individual actions by the forklift drivers as well as for packing personnel, so that they can vary the sequence of orders and even exchange their jobs. From the viewpoint of the workers but also of supervisors, the previous practice had demonstrated its value, so that they wanted to retain it in order to be able to manage disturbances and unplanned demands for flexibility.

A similar situation is the case of a *selective digitizer*, an electronics company attempting to set up a "paperless" assembly line with a shopfloor information system. Up to now however this goal could only be achieved provisionally, because the assembly groups continued to use paper documents (such as large drawings) in order to keep an overview of the final assembly process — to the apparent irritation of the plant manager. As the reason for this was given that the necessity for communication and harmonization within the assembly group, such as about short-term construction changes, but also with indirect areas such as the design department in the past were managed without any problems by means of paper documents. In regard to the use of an also newly introduced control system (in the same firm) one shopfloor supervisor stated that it was better — as before — to ask the crane operator when you wanted to know exactly where a particular component was in the assembly run.

In particular, the many necessary coordination and transposition tasks between the virtual and the real levels make necessary the experiential knowledge possessed by workers, which today can scarcely be fully captured and represented digitally. This means that — in a problem familiar to knowledge theory — many tasks rest on an implicit understanding of their requirements and the methods and rules for their execution that often cannot be made fully explicit or sometimes not at all (e.g. Amin and Cohendet, 2004; Autor, 2015). Concretely are mentioned task elements that need flexibility, judgement, social interaction and communication, as well as accumulated experience with particular work procedures. These activity elements are found in cognitive, intellectual jobs that exhibit a high degree of creativity, problem-solving ability, and intuition. An instructive example of this provided the production manager at a technologically high-end appliance manufacturer for the case of sheet-metal forming. Recently, sheet-metal forming processes had been optimized with the help of a simulation system. In the calculated forming process however the material tore with great regularity. At first none of the involved technicians were able to identify the cause of the tearing. Only after a long malfunction analysis could it be determined that the forming machines themselves were set at too extreme bend parameters and the material to be bent thereby tore. The diagnosis of the error was however only possible because an experienced metal-forming technician was consulted who did not rely on the simulation data, but rather on his experienced-based knowledge and a "hands-on" approach to find the cause.

However, experience-based knowledge still also plays in areas of simple manual tasks a central role, where situative adaptiveness and flexible action, social interaction, physical dexterity, and a light touch are needed. One such example for this was found in a company — a *selective digitizer* — manufacturing living-room furniture. In this form textile sitting surfaces of chairs are sewn and the most different materials for this need to be precisely cut out. The repeated attempt to replace this manual work, carried out by skilled women workers, with that of robots, has failed until now. According to the plant manager the main reasons for this were that the seamstresses worked more flexibly than the machines, and optimized the material layouts more economically. Also, they contribute to the desired quality of workmanship a necessary sense of materials differentiation between the often fine variations in textiles, a sense which machines do not possess. Apparently, these are work processes where the needed levels of optimization, quality and flexibility can even today only be achieved in manual work. A prominent firm representative stated succinctly about the situation: "AI won't be sewing our products in ten years either" (FAZ, 2017).

On the one hand it is thus apparent that the work practices of employees are used to correct optimization deficits and to deal with process malfunctions. On the other hand it is probable that the new digital technologies are opening up approaches to new forms of idiosyncratic social behavior, i.e. new combinations of already well-functioning practices and new technology-dependent but informal courses of action. For in each case the well-established mechanism of sociotechnical complementarity is threatened with loss of its previous functionality and companies must continually re-establish the stable, disturbance-free status of processes. Digitized work processes thus become once again an arena of contention particularly surrounding the question of how compatibility can be established between the virtual and actual levels. Here it is ultimately a matter of the "right" interpretation of the data and their translation into work practices and decisions in the course of the work process. The consequence is simply the above-sketched only hesitating change in work structures.

5. Conclusion: is there a foreseeable transformation?

To resume the present findings, the current tendencies in the development of work processes can be characterized as the *updating of work processes* (Helmrich et al., 2016). This term indicates a very moderate pattern of technological and social innovations whereby companies, in the course of digitization, implement new technologies as well as develop qualifications and competencies_proportionally to the existing forms of plant and work organization, but without substantially changing their structures.

Quite apparently a developmental pattern of work is repeating itself that sociologists already in the past have observed as the consequences for work processes with the introduction of IT systems. In the mid-1980s *Joachim Bergmann*, summarizing the research of German sociology of work on the topic of technology and work and the application of microelectronic technologies, could hardly recognize any far-reaching changes in work: "The new technologies were apparently successfully integrated into the existing organizational structures of work; dramatic changes did not occur…" (Bergmann, 1986: 118). A similar finding was demonstrated by results of analyses, in the late 1980s and early 1990's that studied the then beginning networking of production systems under the label "Computer Integrated Manufacturing". It was shown that companies reacted very reservedly to these new technology perspectives and that single networking components in the organization of work were mainly used in a way that scarcely brought about any changes in the work organization or the deployment of personnel (e.g. Hirsch-Kreinsen and Schultz-Wild, 1990).

In light of the repeatedly posited present and foreseeable massive shift to digital technologies, the question is all the same pertinent, in how far the above-sketched pattern of path-dependency also in the future will shape the changes in technology and industrial work, and in how far a fundamentally disruptive change in industrial work — in the context of digitization — is not to be expected. Empirical as well as conceptual reasons speak for why this is, in the long term, thoroughly conceivable.

In the available research findings there is a number of indications of a trend towards structure-changing transformational tendencies. Apparently, in at least a few firms of different digitization levels, newly created developmental potentials for work are being used. The case is described of a selective digitizer's departure from the previous labor-division type of shopfloor organization and its decentralization of planning tasks in the wake of its introduction of a Manufacturing Execution System (MES). The idea here is that specialist workers know best the machines that they set up and on which they work. Basically, each employee in the pilot area should carry out all the necessary tasks — machine setup and programming, as well as operation/maintenance. Another empirical example is the case of a far-reaching digitizer where new digital technologies are increasingly substituting above all low- and semi-skilled jobs on the shopfloor. Here the works council fears that all these jobs will largely disappear and mainly fully automated production in future will need only a few skilled fitters for dealing with malfunctions, some advisory personnel, and software specialists.

However, also in the view of the path-dependency approach disruptive sociotechnical tendencies of change are conceptually not be excluded. Thus *Jürgen Beyer* points to path-dependent developments that are also thoroughly vulnerable to disruptive change, with the end of a path also possible (Beyer, 2010). He stresses that path-dependencies based on the aforementioned mechanism by no means can lead to a long-term lock-in of the existing processes. And it should not be overlooked, that supposed gains of alternative solutions and the respective choices of the actors involved could lead technologically and organizationally to new structures. Also other authors stress the possibility of leaving a path that was once taken. A precondition for this is the ability to understand and to reflect on the mechanisms of path-dependency and to consider alternative paths (Sydow et al., 2009: 702). This situation can occur when the expected advantage of a path change is big enough, the costs of a change is considered small, and thus expectations of greater economic effects on the new path appear plausible.

These general considerations can also be linked to the the present digitization discourse, which urge a departure from the dominant path-dependency of companies: Company decisionmaking processes and the constellation of the actors involved can change, with the consequence that the small-step optimization mechanisms of the existing structures are no longer seen as sufficient, and strategies of a disruptive change are taken up. A reason for this can be the not-to-be-underestimated influence of the current digitization discourse in which exaggeratedly high expectations of possibly far-reaching economic and social effects of a successful digitization are emphasized. The often shared conviction about this that a far reaching technological, economic, and social transformation has a unavoidable character, may also lead in many companies to new innovation strategies. Additionally, the necessity of introducing the new technologies as comprehensibly and rapidly as possible, is underscored by the constant reminders of already successful digitized companies. Not least, such successful company cases encourage an intensive examination of the new technological potentials, often less with respect to performance-increasing aspects, than those of legitimation. Company managers also want to avoid risks in future, not be considered unmodern, and it is becoming increasingly difficult to justify not following the digitization trend. Companies are under increased pressure to conform, precisely in regard to digitization and Industry 4.0. This phenomenon can be understood organization-sociologically as a *mimetic isomorphy mechanism* (e.g. Dimaggio and Powell, 1983). In the long term the company actor constellations, which decide about companies' innovation strategies, will also shift. For necessarily, in the long term digital innovations — in comparison to the previously praxis-oriented qualifications (for example through the deployment of new, specialized personnel) — will gain in significance and with that influence decisionmaking criteria in the direction of the expanded and more intensive innovation strategies aiming for digital technologies. Finally, with that the overall to date rather hesitant company innovation processes should speed up.

Beyond that, it is not to be excluded that stabilizing mechanisms, as interpreted above as technical reciprocal and complementary relations of sociotechnical structures, will diminish in their effects. For, the — if at first only partial — introduction of new technologies can, from a certain usefulness level of adaptation, impose a shift and disruptive modification of the existing structures, if further efficiency, and productive synergy effects are to be maintained. An example of this is the employment of AI based production systems. The productivity potential of which can only then be fully exploited when preceding and following processes, in regard to the performance of the new systems, are functionally reorganized and the work processes correspondingly redesigned. Further evidence of the growing pressure for change could be the introduction of new digital-based business models and an extended service orientation of many industrial companies. These innovations will have unavoidable techno-organizational reverse effects on the existing internal processes and impart pressure towards their more sustained transformation.

References

Amin, A./Cohendet, P. 2004: *Architectures of Knowledge,* Oxford

Autor D. 2015: Why Are There Still So Many Jobs? The History and Future of Workplace Automation. *Journal of Economic Perspectives*, 29 (3), 3 – 30

Arntz, M. et al. 2016: *Arbeitswelt 4.0 – Stand der Digitalisierung in Deutschland.* IAB Kurzbericht 22/2016

Arthur, W. B. 1996: Increasing Returns and the New World of Business. *Harvard Business Review*, July-August 1996, 101 – 109

Avant, R. 2014: The third great Wave. *The Economist*, October 4th 2014, Special Report

Bergmann, J. 1987: Technik und Arbeit. In: Lutz, B. (Ed.): *Technik und sozialer Wandel: Verhandlungen des 23. Deutschen Soziologentages in Hamburg 1986.* Frankfurt, 114 – 134

Beyer, J. 2010: The Same or Not the Same – On the Variety of Mechanisms of Path Dependence. *International Journal of Social Sciences* 5/1. (2010), pp. 1 – 11

BMWi 2016: *Monitoring Report Wirtschaft DIGITAL 2016*, Berlin

Brynjolfsson, E./McAfee, A. 2014: *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies,* Norton

Büchner, S./Kühl, S./Muster, J. 2017: Digitalisierung zähmt keine Menschen. *Frankfurter Allgemeine Zeitung,* 3. Juli 2017

David, P. A. 1986: Understanding the economics of QWERTY: The necessity of history. In W. N. Parker (Ed.): *Economic history and the modern economist.* Oxford, 30 – 49

Dimaggio, P. J./Powell, W. W. (1983). The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields. *American Sociological Review*, 48(2), 147 – 160

Erixon, F./Weigel, B. 2016: *The Innovation Illusion*. New Haven and London

FAZ (Frankfurter Allgemeine Zeitung) 2017: *Künstliche Intelligenz näht auch in zehn Jahren nicht,* 12.09.2017

Forschungsunion and acatech 2013: *Recommendations for implementing the strategic initiative INDUSTRIE 4.0*. Final report of the Industry 4.0 working group, Frankfurt

Funken, C./Schulz-Schaeffer, I. (Ed.) 2008: *Digitalisierung der Arbeitswelt: Zur Neuordnung formaler und informeller Prozesse in Unternehmen*, Wiesbaden

Garibaldo, F./Rebecci,E. 2018: Cyber-physical system. *AI & Society*, 33, 299 - 311

Heidenreich, M. et al. 2009: Die organisatorische Einbettung von Informationstechnologien in einem globalen Entwicklungsprojekt. In: Funken, C./Schulz-Schaeffer, I. (Ed.) 2008: *Digitalisierung der Arbeitswelt: Zur Neuordnung formaler und informeller Prozesse in Unternehmen*. Wiesbaden, 193 – 220

Helmrich, R. et al. 2016: *Digitalisierung der Arbeitslandschaften.* Wissenschaftliche Diskussionspapiere 180, BIBB, Bonn

Hirsch-Kreinsen, H. 2016: Digitization of industrial work: Development paths and prospects *Journal for Labour Market Research*, 49(1), 1-14

Hirsch-Kreinsen, H. 2016a: *„Industry 4.0" as Promising Technology: Emergence, Semantics and Ambivalent Character*. Soziologisches Arbeitspapier TU Dortmund 48 (https://eldorado.tu-dortmund.de/bitstream/2003/35303/1/Promising%20final.pdf)

Hirsch-Kreinsen, H. 2018: Die Pfadabhängigkeit digitalisierter Industriearbeit. *Arbeit*, 27(3): 1 – 21

Hirsch-Kreinsen, H./Schultz-Wild, R. 1990: Implementation Processes of New Technologies – Management Objectives and Interests. *Automatica*, 26(2), 429 – 433

Icks, A. et al. 2017: *Digitalisierungsprozesse von KMU im Verarbeitenden Gewerbe.* IfM-Materialien 255

Kagermann, H. 2014: Chancen von Industrie 4.0 nutzen. In: Bauernhansl, Th./ten Hompel, M./Vogel-Heuser,B. (Ed.): *Industrie 4.0 in Produktion, Automatisierung und Logistik. Anwendung, Technologien*, Migration. Wiesbaden, 603 – 614

Kleinhempel, K./Satzer, A./Steinberger, V. 2015: *Industrie 4.0 im Aufbruch?* Hans-Böckler-Stiftung Mitbestimmungsförderung Nr.5, Düsseldorf

Kuhlmann, M. 2017: *Arbeitsfolgen der Digitalisierung.* Präsentation beim 1. Ergebnisworkshop des HBS-Forschungsverbundes „Digitalisierung im Betrieb", 13. Dez. 2017, Düsseldorf

Leimeister, J. M./Zogaj, S. 2013: *Neue Arbeitsorganisation durch Crowdsourcing. Eine Literaturstudie.* Arbeitspapier der Hans-Böckler-Stiftung, Reihe Arbeit und Soziales, 287, Düsseldorf

Lerch, C./Jäger, A./Malorca, S. 2017: *Wie digital ist Deutschlands Industrie wirklich?* Mitteilungen aus der ISI-Erhebung Modernisierung der Produktion, Ausgabe 71, Karlsruhe

McAffee, A./Brynjolfsson, E. 2017: *Harnessing our Digital Future.* Norton

Mayntz, R. 2003: *Mechanisms in the Analysis of Macro-Social Phenomena.* MPIfG Working Paper 03/3, April 2003

Minssen, H. 2017: Industrie 4.0. Ein Strukturbruch? In: Hoose, F./Beckmann, F./Schönauer, A.-L. (Ed.): *Fortsetzung folgt – Kontinuität und Wandel von Wirtschaft und Gesellschaft*, Wiesbaden, 117 – 135

Pfeiffer S./Lee H./Zirnig C./Suphan A. 2016: *Industrie 4.0 – Qualifizierung 2015,* Studie für den VDMA www.sabine-pfeiffer.de/files/downloads/2016-Pfeiffer-Industrie40-Qualifizierung2025.pdf (accessed: July 15, 2016)

Rifkin, J. 2010: The *Third Industrial Revolution. How Lateral Power is Transforming Energy, the Economy, and the World*. Basingstoke

Saam, M./Steffen, S./Schiel, S. 2016: *Digitalisierung im Mittelstand: Status Quo, aktuelle Entwicklungen und Herausforderungen.* ZEW Mannheim

Schmidt, F. A. 2017: *Arbeitsmärkte in der Plattformökonomie.* Friedrich-Ebert-Stiftung. Bonn

Staab, P. 2016: *Falsche Versprechen. Wachstum im digitalen Kapitalismus.* Hamburg

Sydow, J./Schreyögg, G./Koch, J. 2009: Organizational Path Dependence: Opening the Black Box. *Academy of Management Review*, 34(4), 689 – 709

Sydow, J./Windeler, A./Müller-Seitz, G./Lange, K. 2018: Path constitution analysis: A methodology for understanding path dependence and path creation. In: Alan Bryman & David A. Buchanan (Eds.), *Unconventional Methodology in Organization and Management Research*, Oxford, 255 – 276

The Economist 2017: *Who's afraid of disruption?* Sept. 30, 2017

Wienzek, T. 2018: Typologie Industrie 4.0. In: Wagner, R. (Ed.): *Industrie 4.0 in der Praxis umsetzen – eine Orientierung für mittelständische Unternehmen,* Wiesbaden

Zuboff, S. 2010: Creating value in the age of distributed capitalism. *McKinsey Quarterly*, September 2010 (Internet: mckinsey.com/business-functions/strategy-and-corporate-finance/our-insights/creating-value-in-the-age-of-distributed-capitalism) (accessed: May 11, 2017)

Seit 2014 erschienene Soziologische Arbeitspapiere

Früher erschienene Arbeitspapiere sind auf der folgenden Website zu finden:
https://eldorado.tu-dortmund.de/handle/2003/26532

38/2014	Hartmut Hirsch-Kreinsen Wandel von Produktionsarbeit – „Industrie 4.0" (Januar 2014)
39/2014	Hartmut Hirsch-Kreinsen Financialization of Innovation – the Case of the German Industrial Innovation System (August 2014)
40/2014	Katrin Hahn Innovationsfinanzierung im Spannungsfeld von Risiko und Unsicherheit: Bremsen die gegenwärtigen Finanzmarktbedingungen unternehmerische Innovationen? (Oktober 2014)
41/2015	Daniel Ruppel Hindernisse und Herausforderungen bei der Implementierung von Ganz-heitlichen Produktionssystemen (Januar 2015)
42/2015	Johannes Weyer/Fabian Adelt/Sebastian Hoffmann Governance of complex systems -A multi-level model (Juni 2015)
43/2015	Hartmut Hirsch-Kreinsen Digitalisierung von Arbeit: Folgen, Grenzen und Perspektiven (Oktober 2015)
44/2015	Johannes Weyer/Fabian Adelt/Sebastian Hoffmann Achieving Substainable Mobility (November 2015)
45/2015	Johannes Weyer Can Pilots Still Fly – Role Distribution and Hybrid Interaction in advanced automated Aircraft (November 2015)
46/2016	Hartmut Hirsch-Kreinsen Industrie 4.0 als Technologieversprechen Juni 2016
47/2016	Peter Ittermann, Jonathan Niehaus, Hartmut Hirsch-Kreinsen, Johannes Dregger, Michael ten Hompel Social Manufacturing and LogisticsGestaltung von Arbeit in der digitalen Pro. duktion und Logistik (Oktober 2016)
48/2016	Hartmut Hirsch-Kreinsen “Industry 4.0 as Promising” Technology: Emergence, Semantics and Ambivalent Character (Oktober 2016)

49/2017 Schulz, Maximilian; Wilkesmann, Maximiliane
Einstellung und Bewertung betrieblicher Interessenvertretung von außertariflich und leitenden Angestellten – Studienergebnisse der Führungskräftebefragung in der chemisch-pharmazeutischen Industrie
(April 2017)

50/2017 Ittermann, Peter; Eisenmann, Martin
Hybride Dienstleistungen und Wandel der Arbeit – Herausforderungen und Perspektiven in der Logistik
(November 2017)

51/2017 Wilkesmann, Maximiliane; Lachmann, Maik; Rüsch, Stephanie
Kirchliche Krankenhäuser im strategischen Wandel. Studienergebnisse zur Strategieauswahl und -implementierung in christlichen Krankenhäusern
(November 2017)

52/2018 Hartmut Hirsch-Kreinsen
Arbeit 4.0 – Pfadabhängigkeit statt Disruption
(März 2018)

53/2018 Marlon Philipp; Fabian Adelt
Optionen der politischen Regulierung des Personenverkehrs – Ergebnisse einer Simulationsstudie
(März 2018)

54/2018 Stephanie Steden
Grüne Kapitalisten im System der Finanzierung von Technologieentwicklung – Das Beispiel der Photovoltaik-Branche
(Mai 2018)

55/2018 Ralf Kopp, Peter Ittermann
Konzeptionelle Perspektiven von Arbeit in der digitalisierten Logistik
(November 2018)