**A comparative historical analysis**

**of socio-technological change**

**in Germany and Japan:  
Path dependence and institutional complementarity**

**in digital infrastructure and the world of work since 1950**

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# Synopsis

Production systems require a precise and smooth information exchange between production and consumption. The more successful the information flow between production and consumption, as well as within production itself, the more efficiently products can be produced for the market. The debate in the 1990s opened by the MIT study on *lean production* has roused interest not only in *lean* production itself, but also in smooth information flow between producers and consumers and within the production process (see Hardt and Negli 2003: 301). For example at Toyota, the information exchange within the production process takes place via the *Kanban*-system (also known as “pull-system”), via signaling at individual work stations, or via information boards in production halls. Using these communication methods, the producers connect the [material] with the consumers; in the same way, the consumers connect the material with the producers. Within this production chain, work acts as a medium creating the connection between producers and consumers.

During work in the value chain, a worker sends information on how his/her tool is to be worked, how the material is to be shaped, and to whom the information is to be passed on. Each instance of sending and receiving information by the worker is an instance of communication between the working subject and matter, production, and the customers’ wishes. Thus, as an information bearer, the worker is a key figure in this communication system. The more efficiently product-related information flows, the more efficiently a production process can be designed. At the beginning of the 1970s, Toyota might have found a more efficient communication method and thus a more efficient information flow.

However, communication within Toyotism was analog. Since the 2000s, digitalization discourse has been reflecting on whether the information flow between humans and machines, among machines, and among humans could be carried out digitally in order to increase production efficiency. The theme of increasing efficiency through digitalization can be traced back to producers’ constant efforts to overcome the coordination problem that results from the division of labor. The spatial and temporal distances in value chains engendered by the division of labor have to be connected and coordinated as closely and quickly as possible in order to ensure a smooth production flow. Digitalization was thought to be able to reduce the spatial, temporal and physical distances between departments, workers, tools, and operators in the work process, and hence those between production and consumption, by developing a smoothly running information flow. Binary codes have enabled a reduction of the data weight of single pieces of information and a concurrent increase in the amount of data that can be transferred within a specific time frame. In this context, digitalization shows great potential for overcoming the coordination problem through building more efficient communication systems for the production process.

The way in which the concept of digitalization is applied as a solution to the coordination problem varies depending on the production system, which in turn varies across industries, countries, periods of technological history, and across space and time. Here a production system consists of institutions relating in complementary ways and being subject to constantly changing environmental conditions. Institutional complementarity refers to the momentary state of a production system, maintained by institutions stabilizing in a self-enforcing way. These institutions continuously adapt to changing conditions within and without in order to stabilize mutually. However, an institutional equilibrium can be destabilized by environmental change to the point at which institutions have to be either rebuilt from scratch or modified. Such institutional change is triggered above all by factors like socioeconomic, sociopolitical and socio-technological change, as well as the historical accumulation of sociocultural influences (Greif 1998: 82). Because of the self-enforcing character of institutions standing in relations of complementarity, however, change occurs within the framework of a historically conditioned developmental path, i.e. it is path-dependent (Milgrom and Roberts 1990a: 514; Milgrom and Roberts 1994: Aoki 1994). Thus digitalization can act both as an instrument maintaining institutions poised in a complementary state within a production system, and as a trigger of path-dependent systemic change within a production system, the world of work, and society.

For these reasons, this project encompasses two research approaches, one diachronic and the other synchronic. The former tackles the question of how industries have changed because of digitalization and which dynamics have at times created new configurations of institutional complementary. Each industry, whether machine tools or coal and steel, has developed along its own historical trajectory, influenced by social, political, technological, and cultural conditions. Since a production system once it is established develops along the lines handed down historically, an analysis of the path dependence of production systems and their de- and re-stabilization processes will be the center of this research approach.

The second approach explores the interdependence of institutions at a specific time in specific locations. This approach assumes that institutions in their stable state of complementary interdependence remain self-enforcing and reproduce in order to overcome coordination problems.[[1]](#footnote-1) It is a comparative analysis of the internally closed production systems of interdependent institutions according to industries and countries. In this project, we focus on the effects of the altered digital infrastructure on work in the automotive and electronics industries in Germany and Japan.

An understanding of digitalization as shaped by time and location is the starting point of our research, as we aim to contextualize digitalization both in a historical-diachronic process and in the synchronic-topographical differences and similarities between the industries of Germany and Japan. This comparative analysis evaluates the state of digitalization and its effects on the organization of work through a systematic juxtaposition of empirical facts in the systemic relationships between the macro-, meso- and micro-levels. Methodologically, the research is divided into qualitative and quantitative parts. In the quantitative portion, we generate and analyze data from company surveys. The qualitative portion of the research uses Qualitative Comparative Analysis (QCA) and expert interviews in order to find the specifically German and Japanese configurations.

In our project, we focus on digitalization in four production models which have been dominant in specific periods since the 1950s and on the transition processes between these periods in Germany and Japan (Figure 1). In this context, I regard a production model as a system of interconnected institutions which emerge from interactions between conditionally efficient and strategically acting individuals. An established production model embraces its institutions in their current equilibrium state as the best solution at the present moment; however, the institutions constantly negotiate changing environmental conditions. Digitalization is a tool for improving the efficiency of the communication between institutions, humans and machines, which synchronically and statically remain in equilibrium, but diachronically and dynamically progress in change.

Figure 1: Developmental path of production models and digitalization technologies in Germany and Japan.

**Fordistic   
Mass Production**

**Diversified   
Quality -produktion**

**Innovation Centered Production**

**Industry 4.0**

**Flow Production**

**Lean Production**

**Post Lean Production**

**Society 5.0**

**Germany**

**Japan**

**1950s—1960s: Beginning of the Digitalization in Firms**

**1970s—1980s: Computerization; CIM vs. HdA**

**1990s—2000s: Informatization; Knowledge Management**

**2010s—2020s Digitalization; Networking**

In our project, we focus on the dynamics of institutional change between the subsequent periods of the production model.

This results in three research programs:

1. Part 1: From the beginning of digitalization to computerization

An analysis of the emergence of digitalization and its technological infrastructure from the 1950s to the 1980s in the changing production models of Germany and Japan from a diachronic and synchronic perspective.

1. Part 2: From computerization to “informatization”

An analysis of the developmental dynamics of digitalization from the 1980s to the 2000s in the changing production models of Germany and Japan from a diachronic and synchronic perspective.

1. Part 3: From “informatization” to digitalization

An analysis of the developmental dynamics of digitalization from the 2000s to the 2020s in the changing production models of Germany and Japan from a diachronic and synchronic perspective.

Parts 1 and 2 will each be completed by one research associate. Part 3 will be completed by the author of this proposal acting as the project manager.

# State of the research: Digitalization as systemic change in the world of work

## Part 1: The first dynamic of digitalization Research areas in industrial and work sociology from the 1950s to the 1980s

The deep societal change since the 1950s can be traced back above all to interlocking complications of the post-war era on the socioeconomic, socio-cultural, and socio-technological levels. During this period, technological euphoria led to an unquestioned acceptance of the mechanization of the work process. Popitz et al. in their opus (Popitz et al. 1957: 14) postulate that the uncontrollability and unpredictability of technological development limits the degree to which industrial labor can be planned. However, they conclude that a technological autocracy that would render industrial workers “slaves of the machine” is not likely to occur (Popitz et al. 1957: 25). They argue that the apparent impotence of industrial workers is not grounded in the overbearing power of machines. So-called “machine-controlled labor” or “mechanized labor” evokes images of marionettes and robots and is “a special case of the rule of mechanism over organism” (ibid p. 25).

Machines in fact condition the rhythm of humans, since they are inflexible and hard to regulate once they have been set in motion. For example, the operator of a rolling stand cannot turn it on and off, nor can he/she regulate its speed, so that in fact “the machine is in control of him, rather than the reverse” (Popitz et al. 1957: 105). The worker’s actions at the rolling stand are conditioned by the machine. The acting subject is being objectified by the machines conditioning him/her while the control mechanisms of the machine increasingly take center stage. However, Popitz et al. deny that the operator is merely reacting to the movement of the machine; rather, his action has been ingrained into his body and implicitly internalized to the degree that the process is better described using Max Weber’s expression “active adaptation” (Popitz et al. 1957: 105–106). While machines have a rhythm-imparting and controlling role, the worker controls and defines the work. Thus Popitz et al.’s investigation into the iron and steel industry tackles the relationship between subject and object, one of the central themes of industrial labor research. However, their representation of causal relationships is still dominated by the assumption that technology is at the source of the causal chain of change in industrial societies.

This technological determinism was tightly tied to the Taylorist-Fordist production model. At the level of business organization, the latter favored high production depth (vertical integration) and thus high internal control. It also entailed “long decision paths across many stages of appeal” and apathetic reactions to changing market conditions, and thus a weak orientation towards the customer and coordination difficulties in production chains. Furthermore, it engendered an antagonistic polarization of intellectual vs. manual labor, for example the indirect work of staff departments as opposed to the direct work of the production sector, thereby limiting the production sector’s scope for goal-setting to internal matters. At the level of work organization, a division of labor based on professions and functions led to a tendency towards barriers and exclusionary behavior and thus to forfeiting the potential for interdisciplinary cooperation and the development of transferable key qualifications in workers. Furthermore, status differences structured in vertical hierarchies led to expert dominance and hence to defensive reactions in the workforce and information distortions. Taylorism in work and business organization went hand in hand with Fordist mass production, widespread since the 1950s, and thus with the technological dominance of mass production.

In the first half of the 1970s, the Taylorist-Fordist production model was accompanied, especially in the machine tool industry, by the introduction of *numerical control* (NC) machines, which can be referred to as the prototypes of digitalization. NC machines were programmed in the programming office, while the workforce on the shop floor worked with the machines developed by the programmers. The resulting split of work organization into unqualified mass labor and highly skilled technical work led to a polarization of qualifications inside companies.

Being geared towards mere efficiency, the Taylorist-Fordist production model did not sufficiently take human factors into account. The substitution of traditional craftsmanship by automation and the associated deficit in qualified, interesting, and autonomous activities caused low job satisfaction especially among workers performing repetitive low-level tasks and those supervising machines. Labor union interest in humanizing work in the 1970s was accordingly directed at improving working conditions, especially through shorter working times.

Work and industrial sociology has been researching the relationships between technological and organizational change and work policies within companies since the 1970s (Kern and Schumann 1970, Lutz and Schmidt 1977, Mickler et al. 1976, Naschold and Dörr 1982, Naschold and Jürgens 1982, Beckenbach 1984, Kern and Schumann 1984). This owes not only to the rediscovery of the working class in the strikes of September 1969, but also to the progressing automation of working processes and the associated effects on work and workers’ consciousness (Kern and Schumann 1970).

The introduction of NC machines led to a segmentation of the workforce along a new qualification matrix in which workers controlling production lines (e.g. [Straßenführer]), those carrying out repetitive labor on the shop-floor, line engineers, programmers in the workshop ... and thus relativized the workers’ class consciousness: the Marxist-socialist antagonism between capital and worker seemed to be frayed in face of this re-segmentation: the reorganization of work and qualification structure caused by new forms of mechanization. Against this background, the “politicization of rationalization” has been postulated as a research desideratum in industrial sociology (see Kern and Schumann 1982: 106).

Starting in the early 1980s, Germany saw intensified discussions of the potential for change in traditional German production methods (Kern and Schumann 1984; Lutz 1987). The increased level of mechanization, especially in highly-automated production process, for example in the margarine industry, dissolved the traditional Taylorist division of labor. The switch from the unsatisfactory NC machines to *computer numerical control* (CNC) machines and computer-integrated manufacturing (CIM) gave rise to the complex flexible manufacturing system (“Flexibles Fertigungssystem,” FFS). The new CNC machines integrated programming and optimizing functions, which caused yet another change in the requirements for machine workers, e.g., in the machining process, from an empirical and craft-oriented skill set to a theoretical and abstract one. The workers’ actual machining skills shifted into the area of subconscious background knowledge, whereas “mediatized work,” such as the supervision, control, and programming of machines moved into the foreground as new requirements. This type of work revaluation was one of the results of the “new production concepts” (Kern and Schumann 1984: pp.19).

Altmann and Baethge postulated a tendency towards “systemic radicalization” (Altmann et al. 1986) which characterizes change throughout the value-addition process of the service sector. The authors use “systemic” to refer to change brought about by CIM not only within companies, but also in their relationships. The mechanization of the production process has been regarded as the “central potential for flexibility” (Sauer 1992: 54). However, systemic rationalization researchers did not fully enquire into the essence of flexibilization; they did not question the consequences of systemic rationalization on work and whether these can be brought into agreement with the idea of the “humanization of working life” (German: “Humanisierung der Arbeit,” HdA). Sauer and Döhl (1994: pp.208) point to changes in work organization in which systemic rationalization, specifically working process computerization, has in their view barely introduced flexibility and efficiency, instead limiting the scope for independent action among workers on the *shop floor*. Furthermore, Taylorist forms of work organization persist in weakly mechanized sectors; these additionally face competitive pressures from low-wage countries (Minssen 2006: 91).

During this period, intensified competition over both quality and price led the German industries with the highest output (the automotive, electronics, and chemical industries) to adopt “diversified quality production” as a competitive strategy (Sorge and Streeck 1988: 32). The conceptual core of this strategy consisted and still consists in the following model policy: offering varied products anticipating customer wishes in high-priced market segments by using high technological quality. The fine-tuning of product quality depended on the skilled worker, a bearer of knowledge systematically qualified with the increasing mechanization of production in view. The positive revaluation of the work of skilled workers contributed to a redefinition of the demarcation lines of work polarization as established by empirical research of the 1970s. The valorization of (skilled) workers demonstrated a significant decline in the former dominance of the Taylorist division of labor and its associated hierarchically-functional division lines, as was the case, for example, in the automotive industry (Kern and Schumann 1984: 50–51).

The Taylorist-Fordist production model also gained ground in Japan, although in a modified way. Researchers do not agree on the reasons for this modification. Wada calls the Japanese adaptation of the production model “flow-production” (Wada 1995: 14). He considers the decisive difference between “flow-production” and Fordist mass production to be the fact that the former aims to achieve increased productivity through a restructuration of work and company organization, whereas Fordist mass production tries to achieve the same by using a massive automation of the production process (e.g., by means of conveyor belts and the engine block milling machine) (Wada 1995: 27). Lean production’s preference for restructuration measures at the organizational level over investments in new machines (like in Fordism) is thought to have its roots in the low capital investment capacities of Japanese companies in this period (Wada 1995: 27).

On the other hand, Fujimoto (1994: 30) postulates a “compressed life cycle” of the Japanese production model as compared to the Western three-step model of the development of production models (pre-Fordist, Fordist, and post-Fordist). The Japanese production model is thought to have developed directly out of craft manufacturing into lean production, without implementing the Taylorist-Fordist production model (Fujimoto 1994: 30). He cites the pressure towards the flexibilization of products and production that Japanese companies experienced as a result of a more competitive environment as the reason for this leap.

An important feature of the work organization of “flow-production” was the assignment of three important leader positions per work unit: group leader, process planner, and quality controller. The components produced were controlled directly within the work unit responsible for them. The process planner adjusted the process in such a way that the pace of his work unit fit in with the plan of the production process as a whole. While the work units received instructions from the administrative center, they were themselves responsible for their internal production process and product quality.

Work tasks were partially rotated within work units. Koike called this task rotation on the shop floor “partial job rotation” (Koike 1997: 99). Partial job rotation within one work unit functioned as a buffer for accommodating changes in production volume in case of increasing demand and sick leaves. Surplus skills within work units contributed to a flexible reorganization of tasks assignments within the work unit (Koike 1997: 100).

The digital infrastructure generated in this period and the changes in work organization will be investigated in Part 1 in view of the production model’s transition dynamics from the post-war era into the 1980s.

## Part 2: The second dynamic of digitalization From computerization to “informatization”

At the beginning of the 1990s, the time factor gained importance in the area of innovation, while customer orientation became increasingly central to company policies in the face of increasingly globalized sales, and financial and goods markets. The pace constantly exacted by the market is met by the dynamization of communication between the interfaces of all shared objects, departments, companies, humans, and machines. Meeting the various customer needs required (and requires) a smooth communication flow between production and consumption, enabling quick and flexible reactions to market change, as well as an anticipatory development of market potentials.

The socioeconomic and sociocultural as well as technological changes of the 1990s, particularly the development of information and communication technology, required German companies to strategically redesign their production concept. While “diversified quality production” had encouraged a further loosening of the Taylorist-Fordist work and company organization, these tendencies had remained within bounds. Some highly-automated sectors, such as the margarine industry, even saw a reconsolidation of vertical and horizontal demarcation lines instead (Kern and Schumann 1984: 300). “Bureaucratic clogging” (Kern and Schumann 1984: 48) slowed down information flow within companies and the dynamics of product and process innovation. Furthermore, the concentration on technically fine-tuned quality products clearly did not result in affordable offers, but instead led to a marked hegemony of the producers, i.e., “*over-engineering*” (Kalkowski 1996: 75) that neglected and hampered the communication between production and customer wishes (Baethge and Baethge-Kinsky 1998: 108). The German industry’s competitive advantage, its organizational structure oriented towards professions and functions, was called into question especially due to the communication problems associated with reduced transferable skills (Kern and Sabel 1994; Kern 1996, Baethge and Baethge-Kinsky 1998).

However, the wider introduction of internet technology, and the according increasing digitalization of production and consumption interfaces, brought about an escape from the rigid production and work regime. The production concept shifted from a production-centered approach to “innovation-centered production” (Baethge and Baethge-Kinsky 1998: 108), which could be characterized by the fine-tuning of market and customer relevance, the dynamization of innovation potentials in both incremental and radical ways, and improvements in product quality and cost ratio. It required a very flexible and quickly adapting “process-oriented company and work organization” (Baethge and Schiersmann 1998: 21ff). At this time, the research focus was broadened from the relationship between technological progress and work quality to also include aspects of the value-addition process as a whole, work and company organization, and ways of gaining qualifications. These structures are further systemically linked to institutions such as the labor market, companies, trade unions, authorities regulating the economy, labor market and technological policies, laws concerning worker’s co-determination and occupational safety, as well as professional training, the employment relationship, wages, and all employment-related social security systems (Boyer and Freyssenet 2003: 20 and 43; Baethge and Schiersmann 1998: 19).

The relevance of industrial sociology research increased even more when the MIT study on lean production was first read in Germany at the beginning of the 1990s, presenting it as the best rational production concept. As the industry and trade unions critically investigated lean production, the following characteristics stood out: a faster information flow, smoother communication between production and consumption, and the elimination of redundant elements within the information flow. This raised the following questions within German industrial sociology: (1) Could a simple adoption of the system really provide a more efficient solution to economic processes? (2) How could lean production, having been developed in a foreign cultural environment, be integrated into the industry of a different nation with a different sociocultural and socioeconomic background?

The former question concerns the essence of the model itself, while the latter questions relate tothe compatibility of the model with the extant institutional components of German society. This research question went beyond matters related to the polarization thesis and expanded the horizons of industrial sociology beyond company-internal matters to include perspectives on society as a whole. In this respect, a wider opening of the horizons of industrial sociology has been meaningful (Kern 1998: 124).

The debate on *lean production* introduced the relevance of information flow into the discourses of industrial and work sociology. Nonaka and Takeuchi (1995) showed how knowledge is produced in Japanese companies. At the center of their analysis stands the concept of “unity,” which is understood in contrast to the “polarization” within the Western world. Unity of man and nature, of body and mind, and of self and other are presented as specifically Japanese ways of thinking, elucidating the knowledge production process within Japanese companies (Nonaka and Takeuchi 1995: 40–45). For Nonaka and Takeuchi, a knowledge production process consists of four dynamics of knowledge: externalization, combination, internalization, and socialization. When a company’s activities are aimed at innovation, the externalization process plays the most important role, since innovative ideas initially exist in an implicit form in the workers’ minds. This knowledge creation process is, according to Nonaka and Takeuchi, deeply rooted in Japanese culture and constitutes the reason for Japanese companies’ exceptional ability to develop innovative products.

In this context, research on information flow within and between companies and factories increasingly moved into the foreground of industrial and work sociology. The first dynamic, computerization, had developed in opposition to the lived experience of work, not paying enough attention to the working subject and thus allowing adverse effects such as alienation to develop within the work process. These adverse effects, however, functioned as an impetus towards “informatization,” inducing a dialectical development as the basis for a “reflexive informatization” (Pfeiffer 2004: 88). Thus “informatization” is understood as the historical process of producing and using information within capitalistic production systems (Pfeiffer 2004: 85).

In summary, due to the vocation-specific deployment concept within the German system, rigid divisions were significant at all levels. Continuing professional education was accordingly pursued outside the workplace. Because the concept of professional specialization was missing in Japan, there were less territorial conflicts on the horizontal level. Horizontal mobility enabled job rotation to function as a tool for continuing education already in this period. The main orientation of staff development towards the management level in this first phase of the production model is common to both Germany and Japan. Part 2 explores the increase computer-managed and controlled machines and the corresponding developments in digital infrastructure and changes in work organization.

## Part 3: The third dynamic From “informatization” to digitalization (in the period between the 2000s and 2020s)

Within the globalized arena of intensified competition, new competitive factors like speed, flexibility, price-performance ratio, quality, and sensitivity to market developments and customer wishes were constantly interlocking. Increasing speed required a dynamization of the communication between the interfaces of all shared objects, departments, companies, humans, and machines. In order to meet various customer needs, smooth communication between production and consumption was required to enable flexible reactions to market developments and the anticipatory development of market potentials.

At a socio-technological level, the continuous development of machine tools and machine-supported tools at work enabled ever new forms of work and company organization and work processes. Internet technology in its rapid development since the 2000s created further methods of overcoming the communication problem through a refinement of information and communication technologies (ICT). The Internet of Things (IoT), RAID, BigData, etc. are the keywords describing the further dynamic drivers of the production system in the last decades. The innovation potential of ICT allowed organizations determined to solve coordination problems to continuously develop new forms of information and knowledge management.

This systemic change enables the development of an autopoietically self-organizing and self-controlling production system in the value-adding process. In case of unexpected disturbances in the production process, the Cyber-Physical System (CPS) can, within the manufacturing process itself, autonomously generate analyses, locate and investigate problem areas, and communicate preliminary diagnoses to the relevant staff. This shift in production architecture changes the job requirements facing workers as well.

Technological development in this period is further characterized by a new challenge in the dialectical development between technology and the world of work. Progressing digitalization using binary codes pervasively accelerates interactions across all areas of working life. The dialectic confrontation between matter and the individual is almost constant. This results in continuously accelerating change in working life, industrial relations, work policy, the economy, and society. This in turn leads to institutions similarly transforming reflexively as an adaptation to changing environmental conditions. In order to recognize and evaluate these attempts at adaptation in terms of reflexively generated side-effects (of side-effects), the approach of “institutional reflexivity” is used (Moldaschl 2005).

In Germany, digitalization has been intensively discussed by the government, industrial associations, and researchers under the rubric of “Industrie 4.0” (“Industry 4.0”), whereas in Japan the term “networking factories” is used in the context of industrial policy, and “Society 5.0” is used at the societal level. On March 19th, 2017 both governments signed the so-called “Hannover Declaration,” lending a contractual framework to the German-Japanese collaboration in the digitalization of industrial production.

The German and Japanese sides both agree that a “fourth industrial revolution” could take shape through digitalization, bringing about a deep transformation in all areas of production system architectures. This transformation at the system level also requires a reappraisal of strategies in economic and labor market policies, a restructuring of company and work organization, and a readjustment of competence expectations towards workers on the shop floor. Workers are expected to not only be proficient with machines and knowledgeable about materials, but also able to carry out platform services – such as dealing with the BigData constantly accrued by computers – and hence to possess vast software competencies. Part 3 examines the transition dynamics from “informatization” towards digitalization in Germany and Japan.

In this project, we investigate the transformation of production architectures and its effects on work organization, job profiles and continuing education programs in light of the progressing digitalization of the value-adding process of Germany’s and Japan’s manufacturing industries.

# Theoretical and methodological approaches: Comparative institutional analysis (CIA) in researching digitalization discourse

Digitalization discourse evaluates the path-dependent relationships between technological, strategic and organizational constructs based on the concept of institutional complementarity (MILGROM und ROBERTS 1990a: 514; MILGROM und ROBERTS 1994: AOKI 1994). As postulated by Matthew, institutions comprise both static and dynamic aspects (Matthew 1986: 906). The evolutionary approach is based on this premise, defining an institution as a self-enforcing[[2]](#footnote-2) subsystem evolving along a developmental trajectory over time, as well as potentially maintaining several equilibria at any given point in time (Aoki 2001: 10–12). Within this subsystem, individuals act strategically, i.e., by anticipating others’ actions, in order to maximize their gains. Anticipations are developed based on compressed, and thus incomplete, information that has been implicitly or symbolically internalized by social actors. Thus an institution is the result as well as the very process of continuously recurring interactions among social actors. This is why Aoki defines institutions as follows:

“An institution is a self-sustaining system of shared beliefs about how the game is played. Its substance is a compressed representation of the salient, invariant features of an equilibrium path, perceived by almost all the agents in the domain as relevant to their own strategic choices. As such it governs the strategic interactions of the agents in a self-enforcing manner and in turn is reproduced by their actual choices in a continually changing environment” (Aoki 2001: 26).

Institutions are above all characterized by the tension between continuity along a historical path and a constant potential for change. In this project, we use Aoki’s conceptualization of institutions in combination with the theoretical approach of “comparative institutional analysis” (CIA) because of our research emphasis on continuity and change in the digital infrastructure of work.

## Complementarity and equilibrium

One of the core elements of CIA is the assumption that institutions, once established within a system, remain in complementary relationships and naturally exhibit a certain stability. This relationship can be divided into two sub-types: (1) institutional complementarity and (2) strategic complementarity.

Institutional complementarity is a state in which two or more institutions co-exit, complete each other, and function more effectively as a whole than they do separately. Milgrom and Roberts define institutional complementarity as follows: “each of which fits with the others and makes the others more effective than they would otherwise be” (Milgrom und Roberts 1994: 4).

Within a system of complementary institutions, the properties of the institutions are continuously reproduced. This not only stabilizes individual institutions, but reinforces the system as a whole. Once such an institutional complementarity is established the reproduction process develops in a self-enforcing manner, and the system becomes relatively resilient to both external and internal factors (see Aoki 2000: 11).

Industrial sociology discourse has been discussing institutional complementarity in the context of industrial relations and specific forms of corporate governance since the mid-2000s (Höpner 2005; Amable, Ernst and Palombarini 2005; Crouch et al. 2005). In this context Amable, Ernst and Palombarini refer to two properties: performance and dynamic stability. Two institutions are complementary when their performances mutually optimize each other, and can also be dynamically stabilized (Amable, Ernst and Palombarini 2005: 313). Their research focus was the institutional complementarity between the liquidity of financial markets and the relative strength of trade unions. In their research, they pointed out two viable configurations or states of complementary industrial relations: (1) a complementary combination of strong, liquid financial markets (short-term decisions at the management level) with weak trade unions, and (2) a combination of weak, less liquid financial markets (long-term decisions at the management level) with a corporatist relationship between trade unions and management (Amable, Ernst and Palombarini 2005: 322–326). The various complementary states or forms of industrial relations can be traced back to dynamic interactions between institutions.

While institutional complementarity centers the synergistic effects of institutions in its analysis, the strategic complementarity approach refers to an equilibrium state of actions performed repeatedly in an institutional context. This equilibrium state arises when social actors benefit from imitating each other’s action strategies (Aoki 2000: 11). A typical example is the right or left-sided organization of traffic. If the majority of the population drives on the left, others will benefit from doing the same. Driving on the left is made into a traffic regulation and is continuously reproduced in society. Here the maintenance of this rule has a self-enforcing character. An institution thus exhibits a certain robustness once it is established. Game theory, which is currently being applied in various scientific fields, calls such an equilibrium state a “Nash equilibrium” (see details in Milgrom and Roberts 1990b: 1257–58; Schotter and Schwodiauer 1980: 486–87).

The specific equilibrium state achieved by an institution depends on the strategy chosen by the majority based on available information. Since information is not only statically immanent within society, but is also dynamically transmitted and reproduced, institutional analysis requires a diachronic perspective based on path dependence.

The background of the concept of path dependence is the “Evolutionary Stable Strategy/State” (ESS) approach presented by the biologists Maynard-Smith and Price (Maynard-Smith and Price 1973: 15–16). The core proposition of this approach is as follows: When a population is in an ESS, then any small minority showing divergent behavior will eventually disappear through natural selection (Friedman 1991: 637). An ESS is a strategy optimally adapted to external and internal conditions and spreading through mutual imitation by members. Aoki calls this dynamic of spreading action strategies “best-response evolutionary dynamics” (Aoki 1998: 408). Institutions exhibiting this dynamic are affected by a so-called “institutional inertia,” which makes institutions immune to changes of the initial conditions and allows them to propagate even unintentionally (see Mathews 1986: 913–16). The durability and robustness of institutions and the path-dependence of their development can be traced back to these internal dynamics. Further, the irreversibility and uniqueness of historical development make it possible for a set of institutions to end up in a range of different equilibrium states which are known in CIA as “multiple evolutionary equilibria” (Aoki 2000: 10).

While an equilibrium, once established, exhibits stability, the interplay between robustness and changing external environmental conditions continues. These changing external factors can also destabilize the institutional equilibrium from the inside out and in this way force change. Thus the constant confrontations of institutions with exogenous as well as endogenous factors lead to a continuous evolutionary spiral which Boyer calls “co-evolution.” “Co-evolution” is the process of (in)dependent institutions searching for a new viable configuration whose final shape is only recognized in retrospective. Boyer, as a theorist of the regulation school, considers political processes to be decisive in triggering and controlling “co-evolution” processes.

The evolution of an institutional culture also has the potential to change the other institutions constitutive of a system, in which case history and path dependence become indispensable orientation benchmarks for the evolution of institutions and the resulting transformation of the total system.

## Digitalization in the interplay between equilibrium and path-dependent evolution

Industrial production entails various institutional interactions. At the meso-level, these interactions take place between technological factors and the solutions applied in work organization, as well as between design concepts in company organization and market strategic decisions. At the macro-level, there is an interaction between political institutions whose discourses are reflected in labor market, economic, and wage policies. At the micro-level, interactions between workers and management, as well as relationships between individual work stages/tasks and machine configurations (work and material flow) exert a great influence.

At each level, the elements develop through their mutual interactions into a total system poised in a Nash equilibrium state. The complexity of the developmental processes in digitalization discourse cannot be elucidated by single-cause explanations such as the culturalist approach or technological determinism. The conceptual differences between German and Japanese production models can be traced back to a joint influence of technological, political, economic, and institutional developmental processes, as well as to the occasionally shifting options for strategic choice.

From the research described above one may conclude that the production model, as a complex of interacting institutions, is located in a field of tensions between continuity and change. Developments depend on changing environmental conditions, developmental paths to date, options for making strategic choices and implementing them in both innovative and incremental ways, as well as possibilities for emulation. This is why in this project we focus on six domains in which institutions interact and shape digitalization in production models. These domains and institutions are specific to time and location and are as follows: (1) socioeconomic settings; (2) economic policy decisions at the governmental level; (3) industrial relations; (4) process designs; (5) job designs; and finally (6) human resources development (see Figure 2).

Figure 2. Causal connections between the environment and institutions.



[Socioeconomic change => Economic policy decisions => Industrial relations => Process design => Job design => Human resources development]

These domains and institutions result in a digitalization system which rests in a temporally and spatially conditioned equilibrium and is resilient to exogenous factors without precluding change caused by endogenous mutations or exogenous environmental factors. I regard this as a causal chain of the production model and as the “tertium comparationis” against which both the German and Japanese models of digitalization can be compared. Historical developments and their strategic transformations at the level of company organization will be analyzed along this causal chain. In this context, human resources development for digitalization is the final element of the causal chain. It has been and is still regarded as a core tool for adapting to technological, socioeconomic, sociocultural and social policy conditions.

# Research questions

Digitalization is clearly not a linear and pre-programmed transformation. Rather, it is driven by the respective economic and industrial policies of industrialized countries aiming to support efficient production coordination and thus reduce transaction costs. This is why this intentionally driven change induces consequences in the socioeconomic structures of the respective societies. Specifically, it affects work policy (re)organization such as the design of technological and organizational alternatives and new networking between production systems and humans, as well as decision processes in work policy and restructuring processes in company policy. Thus digitalization has to be analyzed from the perspective of social structure and social systems in order to reveal the full network of relationships between technology, production and work.

Recognizing the influence of technological change on the reorganization processes of company and work policy, and thus on work itself, leads to the following questions regarding technology and social configurations:

* Which social, economic, technological and cultural preconditions were required to set the dynamics of change from one period to the next into motion?
* Which historically inherited factors shape the path dependence of digitalization development in each country?
* Has digitalization remedied the problem of “work polarization” (Kern/Schumann) across the various historical periods, or has it given rise to new forms of work polarization?
* Which adaptation measures have been introduced in professional and continuing education to deal with the respective digital transformation in each country?
* Does digitalization in production facilitate a more efficient mode of production in an ageing society?
* Has digitalization created opportunities for female workers?
* Can digitalization be made compatible with the humanization of working life, or are these concepts contradictory?
* Has digitalization supported a decentralization of work?
* Has digitalization led to a situation in which human creativity threatens to disappear?
* Can digitalization overcome the struggle over working time and the diminished value of the person/individual?
* Who is the architect of digital systems in each period?
* What is the relationship between the effects of digitalization on the body and mind of workers and government biopolitics?
* How has the power structure shifted both between institutions within the production system and within the work organization in the digitalized working process?
* Which were and are the limits of digitalization?
* The question in this regard is whether digitalization has engendered a systemic subsumption of work in the way the subject of work has been subsumed under capital and objectified. In how far has the subjective attitude of workers changed through “informatization,” computerization and digitalization?
* Has digitalization resulted in a systemic subsumption of work in each period? If so, in which way has the working subject been subsumed under capital?
* In how far has digitalization changed the localization of information in machines vs. humans?
* Was/is digitalization the beginning of sociocultural transformation and thus the first element in the causal connection involving systemic rationalization?

# Objectives and work program

## Anticipated total duration of the project

The anticipated duration is 3 years (from April 2020 to March 2023).

## Objectives

The present project investigates socio-technological change in Germany and Japan from a comparative historical perspective with a focus on digitalization and the world of work since the 1950s. The aim is to identify the path-dependent preconditions for digitalization, by, among other things, identifying institutional complementarities in three historical periods as well as essential elements and factors of the transition dynamics of the production model, including work organization and the technological infrastructures of digitalization from the 1950s to the 2020s. Comparative institutional analysis (CIA) is used as a theoretical and methodological approach for working out the path dependence and institutional complementarity in the transformation of digital infrastructure and work in the production models of the automotive and electronics industries of both countries.

Specifically, the three parts of the research outlined above will pursue the following objectives:

Part 1: Working out the path-dependent preconditions and institutional complementarities as well as the transition dynamics from the period of the beginning of digitalization until that of computerization.

Part 2: Working out the path-dependent preconditions and institutional complementarities as well as the transition dynamics from the period of computerization until that of “informatization.”

Part 3: Working out the path-dependent preconditions and institutional complementarities as well as the transition dynamics from the period of “informatization” until that of digitalization.

The research results will be presented in the following ways:

1. Intermediate reports (research papers)
2. Journal articles
3. Conference presentations
4. Publication of three monographs (one for each part)

## Work program

The work program can be divided into three major phases.

Phase 1: April 2020–March 2021In this first phase, literature and source materials relevant to the three parts of the research (e.g., statistics on the degree of digitalization in the industries researched, histories of decisions made in industrial policy and of adaptations in job qualifications for each digitalization period, etc.) will be collected and analyzed, i.e., evaluated according to the objectives presented above. We will develop contacts within the German and Japanese automotive and electronics industries. We will also begin building a database based on our evaluation of statistical data, e.g., that provided by the Federal Institute for Vocational Education and Training (BIBB). In order to collect source materials and carry out our first qualitative interviews (the empirical foundations phase) in Japanese companies we are planning a research trip to Japan in September 2020 for the project coordinator and two research associates. The qualitative interviews in Germany will be held with employees at Bosch, Siemens, and other companies.

For regular meetings and discussions within and beyond the research team, at this phase we will organize a workshop with experts in Germany. Another aim of the workshop will be to define a framework for developing more specific research questions on the basis of the research and analysis of sources already completed. In order to take full advantage of the research stay in Japan, we will also acquire (buy, copy, etc.) Japanese materials.

In this phase, we also plan to contact relevant archives and academic research institutions in Germany and Japan in preparation for the research stay. A research stay in Japan for the project coordinator and one research associate is planned for August. Important source materials will be collected (possibly copied) and further secondary literature will be searched for and/or purchased.

Phase 2: April 2021­–March 2022This phase serves above all for the evaluation of the new source materials collected at the end of Phase 1 during the research stays in Germany and Japan, and its analysis and/or integration into the framework of previous research. A second research stay in Germany and Japan is planned for two research associates and the project manager in August and September 2012. This will be a final opportunity to obtain source materials relevant to newly developed research questions; we plan to visit additional (including not previously contacted) research institutions located in the second phase of the research. We are planning to organize an international conference at Doshisha University in Japan with experts from both Japan and Germany with the support of the economist Prof. Dr. Kazunori Wada.

Phase 3: April 2022–March 2023We will evaluate the materials collected during the first and second research stays in Germany and Japan and begin writing down the research results (planned as three monographs corresponding to the parts of the research program). At the same time, we will intensively exchange ideas with all persons involved in this research project. We will possibly plan another workshop or other public event in cooperation with Prof. Dr. Yoshinori Wada of Doshida University connected to the publication of the research results in Germany and/or Japan. We will also prepare to present the research results at the annual conference of the European Association of Japanese Studies (EAJS) in the summer of 2022 and at other sociology conferences.

# Previous research by the author

I have analyzed the transition dynamics of work and company organization in Germany and Japan in my master’s thesis and published the Japanese part as “Continuing education on the job for industrial workers in Japan – production management and forms of qualification in the Japanese manufacturing industry” (Nishiyama 2006, peer reviewed). In this article, I showed the path-dependence of the development of the production model in Japan and the associated structure of work and continuing education in the manufacturing industry. In the essay “Adding value through creativity in the contents business,” I pointed out five foundational forms of innovation in the Japanese contents industry (Nishiyama 2010, edited by Nishiyama and others). In the essay “The dual structure of the pay and promotion system of Japanese companies,” I demonstrated the institutional connections between economic policy decisions and the inequalities in company pay and promotion system (Nishiyama 2012, peer reviewed). The article “Intellectual property strategies for the contents industry in Japanese economic policy” analyzes the development of economic policy and its function for the dynamics of innovation in the Japanese media industry (Nishiyama 2012, peer reviewed). In August 2012, I organized and moderated a panel on “comparative research on Japanese capitalism” at the conference “Japanologentag.” In this panel discussion, economists, sociologists, and Japanologists worked out the specificities and similarities of Japanese and German capitalism; the result has been published as the conference proceedings “Japanese capitalism between power and market” (eds. Elis and Nishiyama 2017). Furthermore, the article “The genesis of the skilled industrial worker in organized capitalism: the development of social policy and professional training in Germany from 1870 to 1935” (Nishiyama 2019, peer reviewed) constitutes the basis for research on path dependence in Germany.

This previous research provides the basis for the present project, “A comparative historical analysis of socio-technological change in Germany and Japan: path dependence and institutional complementary in digital infrastructure and the world of work since 1950.” The aim of this project is to deepen the analysis of digitalization in the work process and its effects on the lived experience of work and the qualification system in the automotive and electronics industries.

# Type and scope of the expected results

The expected results of this project concern first of all answers to questions regarding the systemic transformation of production architectures, work organization design, and associated job requirements in digitalizing companies in the German and Japanese automotive and electronics industries. From these we can derive insights on the differences and similarities between the path-dependent development of digitalization in these two countries. These expand our knowledge beyond discussions of present methods for overcoming communication and coordination problems. Thus the project may open up opportunities to discover innovative ways of networking between production and consumption as well as how work can function as a medium in the era of digitalization. The comparative research methodology is expected to reveal as-yet-undiscovered path-dependent continuities and transformations in the automotive and electronics industries of the two countries, and so to further clarify the nature of digitalization in the German automotive and electronics industries.

1. The concept of self-referentially closed systems with autopoietic reproduction of their constituents by Luhmann overlaps with the concept of institutions used in comparative institutional analysis (Luhmann 1999: 60-70). [↑](#footnote-ref-1)
2. Game theory assumes that social actors develop an effective and rational action strategy over game repetitions. An effective strategy is applied by social actors for as long as it remains effective and the opponent does not change his strategy of choice. [↑](#footnote-ref-2)