Competing Institutions: Organization of Work and Efficient Reorganization

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Abstract: This paper contributes to recent research on work organization as a key success factor. On the theoretical side, two alternative analytical explanations are combined to an integrated approach, which predicts the existence of a clear cut ranking of organizational systems. In addition, this hierarchy translates into a second ranking, which is related to profitability. Based on econometric methods, these hypotheses are tested empirically. Since most theoretical studies derive the optimality of reorganizing tayloristic production, actual incidence of modern forms of work organization as well as trends in reorganization behavior are also examined.

Keywords: complementarities, institutional economics, systems of work organization.

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Contents

1. Introduction

This paper analyzes alternative modes of work organization and is embedded in the broader discussion on markets and institutions. For the first time, the seminal theoretical discussion on the *organizational revolution* (SNOWER 1998, LINDBECK/ SNOWER 2000) is tested empirically. In a comparative approach, an alternative model is considered, which concentrates on double sided implicit insurance contracts between employer and worker as a modern and flexible instrument in the organizational choice set: Working hours contracts synchronize product demand and product supply, thereby ensuing job security for employees, and moreover, constituting an initial subsystem of modern work organizations (CARSTENSEN 2000, 2001). With modern work organizations we mean well defined systems of mutually Pcomplementary personnel instruments. The latter model and a nested model of both approaches are also investigated empirically.

The organization of work and far–reaching reorganization activities have been identified as key success factors and are of growing importance for long–term firm profitability. Moreover, they are strongly interrelated with the firms innovation patterns on the production side. Both factors can be analyzed as additional factor inputs (cf. *R&D/ knowledge capital*, HALL/ MAIRESSE 1995; *human resource management systems*, TOPKIS 1998). Strong parallels exist to the theory of technological progress (eg. SOLOW 1957, BARRO/ SALA-I-MARTIN 1995).

As underlying factors in the decision problem, we integrate technological complementarities, learning spillovers, and quantitative flexibility. The theoretical part mainly focusses on comparative statics and generates important hypotheses to be investigated in the empirical part of the paper. The empirical analysis targets at three aspects: First, incidence and pace of reorganization are considered and four consistent systems of work organization are identified. Second, the productivity effects of specific alternatives of work organization are examined. Based on the estimation results, the existence of different organizational equilibria is shown. Such equilibria constitute a reorganization hierarchy and can be interpreted as characteristic systems of human resource management (cf. ICHNIOWSKI ET AL. 1997), PIL/ MACDUFFIE 1996).

Of major importance are teamwork and (frontline) worker participation in decision making (*multitasking*) on the one hand as well as versatility of human capital (*multiskilling*) on the other hand. Further, the organizational choice is embedded in the companies innovation policy. Thus, an integrated model is developed and estimated within an augmented production function framework, which is applied to firmlevel panel data for the manufacturing sector in Germany.

In order to catch as much practical relevance as possible, the empirical section explicitly takes incomplete competition and heterogeneous price setting into consideration. Since we observe merely aggregated price levels and, in addition, homogeneous price setting behavior is more than unrealistic, the corresponding omitted variable has to be corrected for. In particular, the two approaches of KLETTE/ GRILICHES 1996 and

CREPON/ DESPLATZ/ MAIRESSE 1999 are augmented and this alternative method is used in the econometric analysis.

The next section deals with the theoretical framework and contains the hypotheses, which will be investigated in the sequel. Section 3. describes the data and discusses the results of the empirical analysis. Section 4. concludes.

2. Theoretical Background

The theoretical arguments are based on two alternative models of work organization, which are embedded in the modern framework of integrated production technology, decreased communication cost, computerization, and product demand fluctuations. Both models emphasize Pareto superiority of a) the holistic organization of work (multitasking and multiskilling) in comparison to the tayloristic organization (mass production and worker specialization), and b) the breathing organization (working hours contracts and multiskilling) against the traditional organization (lacking or weak adaptive potential), respectively.

The massively growing incidence of adaptive forms of work organization in the last decade is regarded as a stylized fact that should be explained by economic theory. The following conditions have been identified as common factors that initiate and amplify the reorganization process: On the more technical side a) increased availability of flexible production technologies and stronger customer orientation/ feed back (eg. MARSDEN 1996), b) massive cost degression due to IT–Systems (eg. BRYNOLFSSON/ HITT 2000), c) increased standard levels of education and learning spillovers (eg. BILS/ KLENOW 2000) are made responsible for the simultaneous introduction of team work, job rotation, and participation of frontline workers in decision making. Supplementarily, it is argued that d) altered worker preferences towards task variety and task variability underscore the process (see. SNOWER 1998). If one focusses more on the output market of firms, the need for sufficient means to cope with demand shocks drives the reorganization process, thus explaining the introduction of flexible schedules of working hours and decentralized communication and decision making, preferably augmented by functional flexibility in teams and multiskilling.

2.1 Efficient (Re)Organization: Complementarities

The first model (LINDBECK/ SNOWER 2000, hereafter LS 2000) discusses the optimal degree of worker specialization between different tasks, when (informal) task complementarities determine output figures. It concentrates on labor as a pivotal input factor and, further, on efficient reorganization. Reorganization itself is defined as change from tayloristic organized work with narrowly defined tasks per worker (i.e. mass production) towards a modern communication based work organization.

The latter includes incomplete specialization of an employee, i.e. multitasking and decentralized decision making.

The second model (CARSTENSEN 2001, hereafter C 2001) takes product demand uncertainty (for example seasonal fluctuation) as given and starts from that. Given the idiosyncratic restriction set, the profit maximizing firm should explore flexibility instruments to imitate actual demand figures. Within the class of quantitative instruments *working time accounts* play a very special role: Given renegotiation proofness, from a cost perspective, they are strictly preferred to their traditional counterparts like overtime work and short–time work. Thus, complementarities between intertemporal working hours transfers and information/ communication channels are derived. Situated in the more general lattice theoretical framework, it can be further shown that well defined complementarities with other instruments of personnel policy exist. In particular, a more thorough complementary structure encompasses additional means like massive investments in human capital (variability) and multiskilling, team work, decentralization of decision making, and is consistently integrated in the firms innovation policy.

Consequently, in the process of reorganization the second model precedes the first model. Admittedly, a superordinate bundle of personnel policy instruments exists, which encompasses allocative flexibility and versatility of human capital, physical capital and time–task–allocation within teams. Moreover, it is characterized by substantial decision making rights of employees. Depending on the valid constraints set, a more or less pronounced alternative of such a holistic work organization will be realized.

Reorganization takes place if and only if expected returns from complementary instruments exceed the additional costs of the organizational change. Subject to the theoretical toolbox (marginal vs. lattice theoretical approach) the discrete switch of the work organization is either formulated within ε–environments (model 1) or within the more generalized topology of sublattices and chains (model 2). The basic arguments of the two approaches are repeated in the next subsection.

2.2 Two Alternative Models

Loosely spoken, each of these theoretical approaches identifies an initial system for a modern work organization and both are part of the same subordinate system context. To formulate things in a set inclusion manner, C 2001 is included in 2000 (LS), i.e. the renegotiation proof working–time–accounts–environment is included in the multitasking–decentralized–decision–making–environment. Thus, modern forms of quantitative flexibility are expected to be enacted prior to the holistic reorganization. This very interesting point is not mentioned by LS 2000. Therefore, it will be examined in the empirical analysis. The latter system can be augmented by timing of further training, remuneration packages and other pecuniary incentives, product and process innovation patterns, duration of product cycles and firm engagement in the

global market, thus identifying the most comprehensive complementarity structure. We begin with a brief summary of the LS 2000 discussion on the holistic organization of work, and then switch over to the more general framework in C 2001, which allows us to derive the minimal sufficient conditions for the existence of a non tayloristic organization.

The model is formulated as a stylized Ricardo–model:[1] Two types of workers ($\mathbf{N} \equiv (N_1, N_2)$) perform two types of tasks ($\left(L^{\mathbf{1}}, L^{\mathbf{2}}\right) \equiv \mathbf{L}$). The firms optimization problem is to determine the profit maximizing degree of worker specialization. In the short run, the only flexible input is labor: N_1 type–1 employees plus N_2 type–2 employees. Total number of workers is the first variable that determines *factor endowment* $\mathbf{L}$ The model comprises the anomaly that factor endowment is measured by *task units*. With capital fixed in the short run, the (two dimensional) task vector defines the production function $Q[\mathbf{L}(.)|\overline{K}]$.

The Ricardo component is captured by the fact that each worker has a comparative advantage in one the two tasks. Correspondingly, he or she is always relatively more productive in performing $L^{\mathbf{1}}$ or is always relatively more productive in performing $L^{\mathbf{2}}$. By assumption, the comparative advantage is distributed differently among the worker types, where — also by assumption and for notational simplicity — type-1 (2) workers are relatively more productive in task 1 (2). The type-*i* specific degree of task specialization[2] is measured by the time allocation schedule $\{\tau_i, (1-\tau_i)\}$, $i = 1, 2$. Variable τ_i denotes the portion of working hours spent in the task of the comparative advantage. Complete specialization corresponds to the corner solution $\tau_1 = \tau_2 = 1$. I.e. $L^{\mathbf{1}}$ ($L^{\mathbf{2}}$) is completely performed by N_1 (N_2). Complete specialization implies one dimensional work, termed singletasking. Incomplete specialization corresponds to multitasking and implements $0 < \tau_1, \tau_2 < 1$. The working hours allocation pattern constitutes the second essential variable that determines the factor endowment of the firm.

The results rely on one critical assumption: the existence of task complementarities. Tasks are interrelated by learning spillovers. The latter are generated during increased specialization and affect the task with the comparative disadvantage. Spillovers materialize through automatic skill transmission between different tasks. Such returns on complementarity *c* have to be compared to the corresponding returns on specialization *s*.

As a consequence, tasks are neither independent, nor is the complementarity effect *c* constant over the support of the time allocation pattern. The optimization problem is solved by determining the profit maximizing τ_i. This defines the time allocation between tasks, or equivalently, the organization of work. Complete specialization is termed *Tayloristic Organization* (TWO), whereas incomplete specialization corresponds to the *Holistic Organization* (HWO). Once a solution is derived, number of

[1] The 2×2–model deals with comparative advantages and international division of labor.

[2] Intratyp specialization patterns do not differ.

employees and work organization are predetermined[3].

The objective function

$$\begin{aligned} \Pi[_{\tau_1,\tau_2,N_1,N_2}] &= Q[L^{\mathbf{1}},\, L^{\mathbf{2}}] - w[\tau_1]\cdot N_1 - w[\tau_2]\cdot N_2 \quad , \qquad (1) \\ \text{with} \quad L^{\mathbf{1}} &= s^1[\tau_1]\cdot N_1 \,+\, c^1[1-\tau_1]\cdot N_1 \,+\, s^1[1-\tau_2]\cdot N_2 \,+\, c^1[\tau_2]\cdot N_2 \,, \\ L^{\mathbf{2}} &= s^2[1-\tau_1]\cdot N_1 \,+\, c^2[\tau_1]\cdot N_1 \,+\, s^2[\tau_2]\cdot N_2 \,+\, c^2[1-\tau_2]\cdot N_2 \,, \end{aligned}$$

is maximized subject to $0 \leq \tau_i \leq 1$ and $N_i \geq 0$ for each of the worker types $i = 1,2$. Additional restrictions outside the short–termed action space are i. current standards of production technologies in general (cf. $Q_{L^1L^2}$), ii. the size of IT– and communication costs as well as iii. overall education standards. w denotes the incentive compatible remuneration level. Q faces the common feature of input complementarities, i.e. the cross partial of $L^{\mathbf{1}}$ and $L^{\mathbf{2}}$ is positive.[4] Current returns to specialization are measured by the $s^i[\cdot]$ terms, whereas $c^i[\cdot]$ captures the mentioned spillovers for $i = 1,2$.

The main results are easily summarized: If an interior solution does not exist, the corner solution of singletasking will be established. In that case the tayloristic organization of work is chosen. Iff an interior solution exists ($\Pi_\tau = 0$) *and* the second order condition is fulfilled ($\Pi_{\tau\tau} < 0$) multitasking and correspondingly the holistic organization of work are chosen, for example as an outcome of the reorganization process. In other words, multitasking will be preferred, when sufficiently large complementarities exist. Thus, the choice of work organization is equivalent to balancing spillovers from inter–task learning and marginal returns to specialization (intra–task learning). Furthermore, learning spillovers are narrowly tied to (continuous investments in) *knowledge capital*. In the empirical analysis, the latter could be operationalized by human capital and R&D–capital, respectively.

Via this channel, knowledge capital and multitasking are interrelated. In addition, the positive effects of HWO are augmented through modern, adaptive and versatile technologies. Proper maintenance and time management in customer relations or customer feedback further enable the process of reorganization. When transferred to a production function framework, this corresponds with factor embedded systems of work organization. Thus, an adequate empirical analysis can be conducted in the style of investigations of embodied and disembodied technological progress.

According to LS 2000, optimality of the work organization termed *multitasking* results from the existence of informal task complementarities or, respectively, learning spillovers and is always combined with teamwork and worker participation in production related issues. Thus, teams and decentralized decision making constitute a

[3] Predetermination of factor inputs is crucial for the consistency of the estimates presented in section 3.

[4] The current strength of complementarity is measured by $\frac{\partial^2 Q}{\partial L^{\mathbf{1}} \partial L^{\mathbf{2}}}$. It is assumed to be exogenous in the short run. A plausible example are the general level of information and production technology.

well–defined initial system within the subordinate context of designing incentive systems or HRM–systems, respectively. Moreover, investments in knowledge capital that aim at multiskilling are linked to multitasking as well.

In comparison to this model, C 2001 predicts a slightly different initial system, which explicitly incorporates product market uncertainties, and is therefore a bit more realistic. Complementarities between the resulting instrument of working hours accounts and additional instruments like team work and decentralized decision making arise at a second stage. Except for the particular contents of the minimal sufficient initial scheme, the results of the two approaches coincide. Admittedly, they differ formally, as C 2001 applies the theory of supermodular optimization due to the lack of differentiability of the underlying objective function, whereas LS 2000 stay in the marginal analytic framework.

Under some weak topological assumptions over the sets of decision variables and constraints and given the profit function is separable into the three components i. sales, ii. variable costs, iii. fixed costs (cf. TOPKIS 1998), the firm maximizes:

$$\Pi(\mathbf{x},\mathbf{r},p,b) \;=\; p\,\overbrace{Q[p,b]}^{\text{realized demand}} - \underbrace{C\big(\overbrace{Q[p,b]}^{\text{market clearing}},\overbrace{b}^{\text{adaption}}\big)}_{\substack{\text{variable costs:}\\ \text{depending on production,}\\ \text{buffering, and adaption}}} - \underbrace{F[\mathbf{x},\mathbf{r},b]}_{\substack{\text{level of fixed costs}\\ \text{flexibility regime } b}} \qquad (2)$$

(Shifter: choice of firm type via $\mathbf{x}$, $\mathbf{r}$)

subject to $Q \geq 0$ and subject to workers' incentive constraint. Here, $\mathbf{x}$ denotes the (vector) of decision variables except the chosen adaption variables. The constraints set is represented by the corresponding parameter vector $\mathbf{r}$, which does not include potential restrictions on flexibility (eg. legally forced overtime premia, upper limits, etc.). Firmlevel flexibility b can be interpreted as *ability to imitate* actual demand figures. It is assumed that b describes a chain, i.e. that all elements can be ranked[5]. In other words: C.p. the position of the flexibility system in b rises with increasing imitation potential. This requirement is automatically fulfilled, when quantitative adaption is considered. As for a given cost level working time accounts as an instrument to instantly adapt to demand figures is strictly preferred to alternative instruments like overtime and short–time (CARSTENSEN 2000), they are the first element within b.

Although equation (2) in principle describes a traditional production framework, the notation slightly differs. Measured output Q merely refers to realized product demand, which might differ from expected or produced outcomes. If occurred, such

[5]For example $\mathbb{R}^1$ is a chain.

differences, e.g. already produced goods that went to inventories, are introduced as a separate component. Depending on the actual amount and on the chosen adaption regime (b), that component incurs variable and/ or fixed costs. Thus, the corresponding profit effects of deviations between effective and expected output figures can be analyzed separately. Corresponding costs can be operationalized by, for example, inventory costs, overtime premiums, paying for scarce capacity, and maintenance costs for working time accounts.

The particular characteristics of the profit function (separability, ranking within b) in combination with the fact that $\Pi(\mathbf{x}, \mathbf{r}, p, b)$ is supermodular introduce complementarities iff the following condition are valid (for a proof in a slightly different context see TOPKIS 1998, 118ff). Correspondingly, the existence of complementarities forces well defined systems of work organization or, respectively, personnel policy, when: 1. Price policy and flexible production via adaption of b are alternative means of product demand control/ imitation (Q rises with $(-p, b)$). 2. The size of b which is required to imply exactly the same demand shift as a 1%age price reduction is smaller at higher price levels. 3. Revenue always exceeds variable costs, i.e. positive contribution margins over the domain of $Q \geq 0$. 4. Additional variable costs that arise according to an augmentation of b are non–negative and, in addition, do not decline with rising output levels, i.e. larger expansion needs are not "benefited" by lower expansion costs. 5. Fixed costs F are submodular in $\mathbf{x}, \mathbf{r}, b$, i.e. cost complementarities between b and $\mathbf{x}, \mathbf{r}$ exist. Commonly used information and communication channels or additional functional flexibility in teams are two candidates within $\mathbf{x}$ for cost complementarity.

To conclude, supermodularity of Π is equivalent to the following statement on monotone comparative statics for work organizations (see the proof for product quality in TOPKIS 1998):

Proposition 1 ***(Comparative statics):*** *The equilibrium level of maximized profit* Π *describes an ascending order with the ordering variable b. Profit jumps are larger at higher levels of b. Particularly, switching from "no adaption" to "intertemporal hours transfers" in working time accounts introduces a positive shift in equilibrium profits.*

Thus, working time accounts are a sensible instrument in the work organization action space and, therefore, constitute a well defined initial system for reorganization. Two further points have to be mentioned:

- Working time accounts have to be enacted as durable means of flexible production and workers have to agree to it. For a given incentive constraint, these requirements are fulfilled when working time accounts are initialized as a double sided insurance contract (CARSTENSEN 2000). In that case, workers cover their firm from transitory demand shocks (profitability effect) *and* the firm covers employees from dismissal risks due to reallocative shocks (job security effect). Existence and enforceability of this insurance contract depend on the crucial condition of renegotiation proofness and spot contract implementability.

CHIAPPORI ET AL. 1994 have pointed out that a closed credit market, where both parties, creditor and debtor, are able to verify the amount of savings and credits guarantees spot implementability (which further implies renegotiation proofness). Since working hours accounts, by definition, constitute a closed inner firm credit market between worker and firm, both conditions are fulfilled, if employees can verify the size of hours transfers. I.e. workers must be able to assess *saved hours* compared to *standard hours*. In practice, proper information for frontline employees about demand figures and other financial aspects should establish this requirement.

- From cost complementarities in F, i.e. from subadditivity or submodularity, respectively, the existence of a broader complementary structure follows. According to parallels between quantitative and functional flexibility, teams and decentralized decision making, i.e. the holistic work organization, are also part of this encompassing HRM–system.

Augmented models should include monetary incentives as well. The empirical section will account for that. The next subsection contains the hypotheses.

2.3 Hypotheses

To conclude for the empirical analysis, reorganization induces productivity enhancing effects. One major task for the empirical investigation will be to proof shifts in productivity and to examine, whether corresponding effects are disembodied and/ or embodied. If the existence of embodied effects can be shown, it has to be investigated, which input factors are more affected than others, and whether the embodied effects are of the same sign over different inputs. Another important task is to statistically describe the incidence of different systems of work organization. In addition, it is an open question, whether the observable reorganization process towards holistic organized firms is in fact as massive as argued by LINDBECK/ SNOWER 2000.

As argued within the general framework of supermodular optimization, the combination of working time accounts and a decentralized information and communication system constitutes an initial step in an ascending restructuring hierarchy. Thus, a snapshot over the whole economy should reveal a few organization–type equilibria, which represent a ranking. In such a rank order, tayloristic production builds the bottom end, whereas holistic production is the top end. Working time accounts form an intermediate layer, when no additional instruments are effective. For the integrated model, we predict that the reorganization process discussed in LS 2000 is preceded by the introduction of hours transfers and communication channels, and further, that on the aggregate level of the manufacturing sector a well defined hierarchy of work organizations exists.

This hierarchy can be directly converted to a hierarchy in profits: The tayloristic organization (TWO) is tied to the lowest level of equilibrium profits, the next higher level

is reached by renegotiation proof working time accounts (WTA_ICS), and the highest level is reached by the holistic work organization (HWO).

It is also worth to explicitly estimate the decision between tayloristic and holistic organization of work. In this context, we predict that the probability for reorganization from TWO towards HWO is positively influenced a) by the degree of technological complementarity $Q_{L^1\ L^2}$, b) by the pace of cost degression for IT–systems, and c) with more pronounced workers preferences for task variety and/ or task variability.

Technological complementarities are implemented through innovative and flexible technology of production and distribution. With modern IT–systems, potential learning spillovers from multitasking and multiskilling increase faster than returns from ongoing specialization. Basically, we expect positive embodied effects of non-tayloristic work organizations in knowledge capital, which are higher for elaborated multitasking systems. In addition, shorter product life cycles or, equivalently, higher numbers of innovations per 5–year spells should correspond with the holistic organization.

Worker preferences for versatile work are related to lowered levels of incentive compatible wages. Since it is more than likely that firms do not lower existing wage levels, an interesting question in the empirical analysis will be, whether additional productivity effects result from *preference–driven* reorganization or, respectively, whether different subsystems within the class of HWO can be identified. Last not least, it has to be expected that potential productivity effects differ by such within–class subsystems.

3. Empirical Analysis

This section describes the data, the procedure for correcting the heterogeneity bias caused by firmlevel price setting, and discusses the empirical results. The explained variable is labor productivity. The system of work organization is measured by an indicator variable and is integrated as an explanatory variable. Models that control for selection into specific organization types are considered in addition to traditional production estimates, since the choice of work organization is not necessarily independent from expected productivity changes.

3.1 Data

The empirical analysis uses the Hannover Panel. This is a panel data set within the manufacturing sector in Germany. It contains annual information for 1000 enterprises and encompasses the period from 1993 to 1997. The economic contents of the yearly questionnaires are quite similar to British and Australian WIRS (workplace and industrial relations survey, MILLWARD 1993). A lot of information used in the analysis has been conducted for several periods, but the complete information set that is needed

to construct the superordinate system of work organization is only available once per firm.

The questionnaire completely lacks physical capital and investment in productive capital. Therefore, capital is imputed from the records of the German central bank according to sales–classes/ ISIC Rev. 3–classification cells (DEUTSCHE BUNDESBANK 1999, STATISTISCHES BUNDESAMT 1993). The documented capital shares are weighted with firmlevel revenue to construct physical capital.

In addition, industry price level is integrated as a deflator for sales. Since we use deflated sales as an instrument for firmlevel output, the production functions are not estimated consistently, unless price setting within each industry is homogeneous. This argument will be elucidated next and a suitable procedure for correcting the price bias is introduced. This approach uses the market share of the firm and industry production as additional variables.

3.2 Incomplete Markets: Correcting for Heterogeneous Prices

Basically, the price bias exists, because the endogenous variable *output per capita* is not observable. Rather, deflated per capita value added is measured. The size of the bias is measured by the difference between the two variables. It can be quantified by integrating the common microeconomic model of incomplete competition (DIXIT/ STIGLITZ 1977) into the work organization framework.

The logarithmic mathematical model is $\ln Q_{it} - \ln L_{it}$, whereas lnLPROD is observed (the derived formula is an extension of CREPON/ DESPLATZ/ MAIRESSE 1999 and KLETTE/ GRILICHES 1996):

$$\ln\left(\frac{(1-s_{it}^{\text{Mat}})\cdot P_{it}\cdot Q_{it}}{L_{it}\cdot P_{It}}\right) = \ln(1-s_{it}^{\text{Mat}}) + \boxed{\ln Q_{it} - \ln L_{it}} + \underbrace{\ln P_{it} - \ln P_{it}}_{\substack{\text{heterogeneity}\\ \text{bias}}} \quad , \qquad (3)$$

with the firmlevel price P_i and industry price level P_I. For simplicity, the revenue share of materials is assumed constant ($s_{it}^{\text{Mat}} = \overline{sm}$)[6] and disregarded for the moment. The price bias is then given by:

$$\ln P_i - \ln P_I = \underbrace{\ln P_i - \ln P_S}_{\substack{\text{market segment}\\ \text{model}}} + \underbrace{\ln P_S - \ln P_I}_{\substack{\text{sector wide}\\ \text{model}}} \quad . \qquad (4)$$

[6] It is sufficient to suppose firm specific time invariance. Interfirm variation of s^{Mat} is no problem, when panel estimation is applied.

P_S denotes the price level in the firm's own market segment. The term in equation (4) can be calculated exactly, when preferences for product variety exist. Then the microeconomic model of monopolistic competition (eg. DIXIT/ STIGLITZ 1977) can be applied. Since the model predicts zero profits in the long run, it is sensible to assume the existence of market entry barriers, so that persistent rents are not ruled out a priori. The analytical advantage of this approach is the following: The size of the heterogeneity bias is consistently derived from consumer preferences and demand conditions.

Utility maximizing consumers and profit maximizing firms imply:

$$Q_{it} \;=\; Q_{St}\left(\frac{P_{it}}{P_{St}}\right)^{\eta_S} \quad , \qquad Q_{St} \;=\; Q_{It}\left(\frac{P_{St}}{P_{It}}\right)^{\eta_I} \quad . \tag{5}$$

Here, η_S (η_I) denotes demand elasticity in the market segment of the firm (within the industry). It is determined by elasticity of substitution within the relevant demarcation. Profit maximizing price setting behavior implies the following relation among demand elasticity η and markup $\mu = \frac{\text{price}}{\text{marginal costs}}$:

$$\eta_S = \frac{\mu_S}{1-\mu_S} \quad , \qquad \eta_I = \frac{\mu_I}{1-\mu_I} \quad . \tag{6}$$

To summarize, the bias is:

$$\left(\mu_S^{-1} - \mu_I^{-1}\right) \cdot \underbrace{[\ln Q_{it} - \ln Q_{St}]}_{\ln(\text{market share})} + \left(\mu_I^{-1} - 1\right) \cdot \ln Q_{it} - \left(\mu_I^{-1} - 1\right) \cdot \ln Q_{It} \tag{7}$$

and labor productivity $\ln \mathrm{LPROD}$ is:

$$\begin{aligned} \ln \mathrm{LPROD} \;=\; & \mu_I^{-1} \cdot \ln Q_{it} \;-\; \ln L_{it} \\ & + \left(\mu_S^{-1} - \mu_I^{-1}\right) \cdot [\ln Q_{it} - \ln Q_{St}] \\ & + \left(1 - \mu_I^{-1}\right) \cdot \ln Q_{It} \;+\; \delta_{it} \quad , \end{aligned} \tag{8}$$

with $\delta_{it} = \ln(1 - s_{it}^{\mathrm{Mat}})$. Consequently, the bias can be eliminated, if the *market share of the firm* ($\ln \mathrm{Share}_{it}$) and *industry level production* ($\ln Q_{It}$) are integrated as additional explanatory variables. Respective models for total factor productivity should integrate annual growth rates.

The correction term is applied in the econometric estimates. The results of the empirical analysis are presented in the next section. The empirical specification for $L+1$ different modes of work organization WO is[7]:

$$\begin{aligned}
\ln \mathrm{lprod}_{it} \;=\; & \beta_0 \;+\; \beta_1 \ln Q_{It} \;+\beta_2 \ln \mathrm{Share}_{it} \;+\beta_3 \ln \mathrm{L}_{it} \\
& + \beta_4 \left(\ln \mathrm{K}_{it} - \ln \mathrm{L}_{it}\right) \;+\; \beta_5 \left(\ln \mathrm{KnC}_{it} - \ln \mathrm{L}_{it}\right) \;+\; \beta_6 t \\
& + \sum_{l=1}^{L} \beta_{6+l} \cdot 1(WO_l) \;+\; \sum_{l=1}^{L} \beta_{6+L+l} \cdot 1(WO_l) \ln L_{it} \\
& + \sum_{l=1}^{L} \beta_{6+2L+l} \cdot 1(WO_l) \left(\ln \mathrm{K}_{it} - \ln \mathrm{L}_{it}\right) \\
& + \sum_{l=1}^{L} \beta_{6+3L+l} \cdot 1(WO_l) \left(\ln \mathrm{KnC}_{it} - \ln \mathrm{L}_{it}\right) \;+\; u_{it} \quad ,
\end{aligned} \tag{9}$$

with the indicator variable $1(WO_l)$, knowledge capital KnC, physical capital K, labor input L. The estimated parameter vector $(\beta_1, \ldots, \beta_6)$ of the reduced form corresponds to the following structural parameters, where γ_0^{Taylor} measures the shift parameter of the baseline organization (TWO) and ε_j denotes factor elasticity of input j:

$$\begin{pmatrix} \beta_0 \\ \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \\ \beta_5 \\ \beta_6 \end{pmatrix} = \begin{pmatrix} \gamma_0^{\text{Taylor}}/\mu_I \\ 1 - \frac{1}{\mu_I} \\ \mu_m^{-1} - \mu_I^{-1} \\ \frac{\varepsilon_k + \varepsilon_l + \varepsilon_{wk}}{\mu_I} - 1 \\ \varepsilon_k/\mu_I \\ \varepsilon_{wk}/\mu_I \\ \gamma_0^{\text{WO}_1}/\mu_I \end{pmatrix} \tag{10}$$

The error term u_{it} can be firm specific and autocorrelated[8]: $u_{it} = \rho_i u_{i,t-1} + \nu_i + \varepsilon_{it}$, with $\varepsilon_{it} \sim \text{iid}(0, \sigma_\varepsilon^2)$. The applied estimation methods account for such error structure (see KMENTA 1997).

[7] One of these systems (e.g. Taylor) has to be identified as the base system WO_0, corresponding to $\beta_0 \equiv \text{const.}(\text{Taylor})$, $\beta_3 \equiv \text{scale}(\text{Taylor})$, etc.

[8] Tests justify an AR(1) process.

3.3 Results

Table 1 shows the incidence of the alternative integrated systems of work organization. In addition, reorganization dynamics could be calculated for the holistic organization in the definition of LS 2000. The integrated systems have been identified in cluster analyses.

In particular, $\mathbf{HWO}_{pr}$ possesses the LS 2000 multitasking and participation characteristics, but in addition, this type of holistic organization seems to be introduced in accordance with worker preferences for versatile work and within an overall firm framework of a sufficiently multiskilled workforce. This system faces the strongest customer orientation and the highest proportion of group based remuneration. In comparison to this obviously preferences–driven subsystem, the $\mathbf{HWO}_{tc}$ system describes the technology–driven counterpart within the class of holistic organizations. In accordance with the hypotheses in section 2.3, working time accounts and detailed communication system are in fact substantial part of each HWO. In addition, the *tc*–variant is characterized by relatively less emphasis on product quality and relatively more emphasis on price strategies.

The initial system that corresponds with quantitative flexibility as defined by *b* in section 2.2 is **WTA_ICS**. It shows massive investments in human capital and in on the job training, fostering both, inter task and intra task learning. In addition, quality and the absolute necessity for proper time management are pronounced in each of the firms that have been assigned to this starting scheme. Moreover, the monetary compensation package contains a high–level CES–basket of individual and group based incentives. This strong monetary component corresponds with the minor proportion of workers, which are involved in teamwork.

The tayloristic regime **Taylor** will be regarded as a baseline regime. It is characterized by almost none intertemporal hours transfer, by minor training investments, by moderate teamwork (proportion of blue collar employees engaged in teamwork about 15%), by virtually no participation in decentralized decision making and by substantial incidence of piece rates.

From a dynamic perspective, incidence of the multitask organization of work is in fact growing, but at a much less dramatic rate than predicted by SNOWER 1998 and LINDBECK/ SNOWER 2000.

The duration of product cycles in holistic firms vs. tayloristic firms and the differences in labor productivity, broken down by integrated systems, are also regarded from a descriptive perspective. At least on a descriptive basis, it seems that product cycles of holistic firms are in fact shorter (table 2) compared to their tayloristic counterparts.

A first glimpse on the productivity figures reveals no significant differences among the alternative branches of reorganized firms. Here it seems that the crucial level jump occurs from tayloristic work organization to a more flexible and/ or more participative system (table 3).

Table 1: Hierarchy of alternative work systems and reorganization activity

Work System ➟	**HWO$_{pr}$**	**HWO$_{tc}$**	**WTA_ICS**	**Taylor**	Firms
Cross Section Portion [%]	21.4	10.6	13.3	54.7	942
		Multitasking & Participation			
Incidence	**1993**	**1994**	**1995**	**1996**	Mean
Holistic	18.9	26.5	33.5	38.5	28.6
• Team	47.2	58.9	68.9	70.1	59.6
• Decision Making	41.5	42.1	44.6	48.2	43.8
Introduction					
Holistic		9.9	12.1	6.1	8.5
• Team		14.9	12.5	2.7	10.0
• Decision Making		2.6	8.9	12.4	5.5
Abolition					
Holistic		3.6	6.6	3.2	3.5
• Team		5.4	7.3	1.2	3.7
• Decision Making		2.2	6.6	8.5	4.0

Annual percentage figures.

Table 2: Multitasking and shortened product cycles

	Holistic	(N_t)	Tayloristic	(N_t)	level of sign.
1993	0.83	(93)	1.05	(318)	0.01
1994	0.85	(124)	1.06	(288)	0.01
1995	0.84	(165)	1.09	(258)	0.01
1995	0.88	(203)	1.10	(226)	0.01

T-Tests for differences in average duration of product cycle, normalization: average product life (whole sample): 1. Group based number of cases: N_t. level of significance of mean difference (%.)

It is up to the econometric analysis to proof differences between the alternative subsystems of HWO. In this context, we focus on two broader lines of argumentation: On the one hand, we estimate productivity equations including regime information and embodied effects. On the other hand, we estimate separate treatment regressions for each subsystem of work organization in order to identify diverging determinants of

Table 3: Profitability ranking and system ranking

Work System ➟	**HWO**$_{pr}$	**HWO**$_{tc}$	**WTA_ICS**	**Taylor**
	11.65	11.62	11.60	11.52
	(0.38)	(0.42)	(0.39)	(0.36)

Oneway ANOVA for differences in log of labor productivity. Significant differences only between **Taylor** and all other regimes. Standard deviation in parantheses. Test on equality of variances (sign. level): 0.049*.

the organizational choice and alternative channels of productivity transmission. The summary statistics can be found in table 4.

Table 4: Summary statistics (in log**s, except dummy variables)**

Variable	Mean	Standard Deviation
LABOR: number of employees,	4.47	1.18
LPROD: labor productivity, (deflated by industry prices),	11.58	0.38
H_QI: industry production level, 1993$\equiv$ 0,	-0.01	0.06
H_MSHA: market share,	2.38	1.27
KINT: $(\ln K - \ln L)$, capital intensity	10.49	0.63
KnCINT: intensity of knowledge capital [a], $(\ln KnC - \ln L)$.	8.68	2.89
➪ see table 3 for work system definitions, estimates base system: **Taylor**.		
Embodied Effects of the Work Systems and Trend		
$*$_KnCINT	...embodied in knowledge capital	
$*$_KINT	...embodied in physical capital	
$*$_LABOR	...effect on scale elasticity	
T93...T96	year dummies included, joint significance always below 5%-level	
S1...S28	sector dummies included, joint significance always below 5%-level	

[a] Sum of annual investments in human capital and R&D, starting value: perpetual inventory method.
Data sources: The Hannover Panel, covered periods: 1993–1997 (BRAND ET AL. 1998), German Central Bank (DEUTSCHE BUNDESBANK 1999), Statistical Office (STATISTISCHES BUNDESAMT 1994; 1995a; 1995b; 1996; 1997a, 1997b).

Table 5 contains treatment effects regressions, which correct for potential selectivity bias. Due to the essential role of multitasking in each of the elaborated forms of work

organization, multitasking is taken as the respective decision variable. Two alternative versions are presented: First, the estimate is run over the whole sample, thus assuming the pure LS 2000 environment. Such procedure neglects the possibility that effects related to organizational change may differ between the regime switches (i.e. column (5) assumes the multitasking effect on productivity is the same for a reorganization from **Taylor** to **WTA_ICS** compared to a switch from **WTA_ICS** to **HWO**$_{tc}$). This assumption is relaxed in column (1) to (4), which treat the four systems separately.

Except for the tayloristic firm, the negative sign of the selection term is persistent and reasonable, since we would expect profit maximizing behavior of firms. Significance of the selection term is restricted to the **WTA_ICS** system. It is, however, only borderline significant. Thus, table 6 uses dummy variables for the alternative systems of work organization in order to capture the system specific effects on productivity (compared to **Taylor**).

Table 5: *Holistic* reorganization: Treatment effects equations. Dependent variable: labor productivity

↓ **Explanatory** ↓	**HWO**$_{pr}$	**HWO**$_{tc}$	**WTA_ICS**	**Taylor**	**pooled**
variables	(1)	(2)	(3)	(4)	(5)
KnCINT	−0.015	0.054∗∗	0.035∗	−0.004	0.002
KINT	0.611∗∗	0.664∗∗	0.691∗∗	0.721∗∗	0.561∗∗
LABOR	0.026	0.040	−0.109∗	0.029∗	0.032∗∗
H_QI	0.153	0.169∗	0.160∗∗	0.180∗∗	0.174∗∗
H_MSHA	0.003	0.037	0.001	0.008	0.021∗∗
const.	++∗∗	++∗∗	++∗∗	+∗∗	
MULTITASKING	0.087	0.149	0.255°	0.008	0.105°
Selection	−0.07	−0.13	−0.165°	0.014	−0.046
quality	+	+	+°	+	+∗∗
preferences	+∗∗	+	+	+∗∗	+∗∗
flexibility	+	+∗	−	+∗∗	+∗
inter–task	+∗	+	+	+∗	+∗
hours transfer	+	−	+∗	+∗	+
pace	+	−	+	−∗	+
const.	−∗∗	−	−∗	−−∗∗	
time controls	∗∗	∗∗	∗∗	∗∗	∗∗
industry controls	∗∗	∗∗	∗∗	∗∗	∗∗
Prob $> \chi^2$	0.00	0.00	0.00	0.00	0.00

Levels of significance: °: 10%, *: 5%, **: 1%.

A closer look to table 5 reveals the information that the decision process on sys-

tem upgrading differs between the four regimes. For example, $\mathbf{HWO}_{pr}$ and $\mathbf{HWO}_{tc}$ show no significant influence of working time accounts on the multitasking decision, whereas their appearance predominantly drives the switch from **Taylor** to **WTA_ICS** and, in combination with quality control, from **WTA_ICS** to $\mathbf{HWO}_{tc}$. It seems that the lack of modern work organization is, by all likelihood, caused by the high pace of production. Nevertheless, firms that operate in such a mass production regime are able to introduce holistic elements[9], if the whole bundle of potential determinants of organizational change is effective (column (4)). Thus, the threshold for introducing multitasking in the singletasking, i.e. tayloristic, environment is more likely to be crossed, when a) worker preferences for versatile work, b) flexibility enhancing process innovations, c) hours transfers, and d) investments in inter task learning are existent simultaneously. This is in line with the argumentation on complementarities.

The disembodied effect of knowledge capital on productivity also varies with the practiced work organization. For the preference related environments (multitasking–subsystem and tayloristic–subsystem) no productivity effect is observed in the treatment regressions. On the other hand, knowledge capital is an important input factor in the technological driven multitasking–subsystem $\mathbf{HWO}_{tc}$ as well as in the flexibility regime **WTA_ICS**. This underscores the discussion on complementarities of skill variety and versatile production technology.

The productivity estimates can be found in table 6: Model (1) represents the basic estimation via OLS. Model (2) uses the auxiliary residual regression $u_t = \rho u_{t-1} + \varepsilon_t$ to examine the correlation coefficient ρ. Since first order autocorrelation is proven, ($\widehat{\rho} = 0.63$, Durbin–Watson–Statistic after (prior to) AR(1)–correction 1.73 (0.49)), AR(1) models are also applied, when panel applications are estimated. In particular, we distinguish between common AR(1) process (column (4)) and firm specific transmission trends (column(5)).

To summarize, except for the highest ranked system $\mathbf{HWO}_{pr}$, the measurable productivity effect of reorganization is negligible. This result is in accordance with the complementarity approach that emphasizes the need for encompassing reorganization. Thus, the expected equilibrium shift is observed only for the preferences–driven variant of the multitasking regime. In comparison, the technology–driven counterpart $\mathbf{HWO}_{tc}$ is always positively embodied in the input vector, thereby generating (borderline) significant increases in the scale elasticity. The results for the preceding initial scheme **WTA_ICS** are mixed and depend heavily on the econometric specification. If anything can be concluded for that layer of the work organization ranking, it is the positive interaction with knowledge capital. At least this result is in line with the literature that identifies inter task learning and multiskilling as necessary determinants or modern work organizations (cf. LINDBECK/ SNOWER 2000).

[9] See also the discussion of an *organizational revolution* in SNOWER 1998.

Table 6: Organization of work and labor productivity

Explanatory ↓ variables	(1) OLS pooled	(2) PW pooled	(3) RE Panel	(4) AR(1)-RE Panel	(5) HETPW Panel
	Dependent variable: LPROD				
KnCINT	0.006°	0.007	0.005	0.005	0.004
$\mathbf{HWO}_{pr}$	0.469°	19.091	0.136	0.198	0.478°
$\mathbf{HWO}_{tc}$	−0.177	11.614	−0.101	−0.024	0.223
WTA_ICS	0.573	−14.389	0.189	0.249	0.412
$\mathbf{HWO}_{pr}$_KnCINT	0.004	0.116	0.007	0.008	0.015*
$\mathbf{HWO}_{tc}$_KnCINT	0.001	0.068	0.007	0.006	0.008
WTA_ICS_KnCINT	0.007	0.979	0.005	0.006	0.008
$\mathbf{HWO}_{pr}$_KINT	−0.052*	0.289	−0.023	−0.029	−0.052*
$\mathbf{HWO}_{tc}$_KINT	−0.002	−0.002	−0.019	−0.025	−0.043
WTA_ICS_KINT	−0.067°	0.186	−0.032	−0.038	−0.053
$\mathbf{HWO}_{pr}$_LABOR	0.012	0.584*	0.015	0.013	−0.003
$\mathbf{HWO}_{tc}$_LABOR	0.052*	0.432*	0.059*	−0.058*	0.050
WTA_ICS_LABOR	0.017	0.964	0.024	0.022	0.021
LABOR	0.021*	−0.345*	0.010	0.013	0.003
KINT	0.571**	0.769**	0.620**	0.611**	0.427**
H_QI	**	**	**	**	**
H_MSHA	**		*	*	°
const.	.+**	.+**	.+**	.+**	+**
observations	1180	595	1180/494	1180	1180
R^2	0.59	0.39		0.44	0.58
time	**	**	**	**	**
sector	**	**	**	**	**
joint sign..$\mathbf{HWO}_{pr}$	°	*			**
joint sign.c.$\mathbf{HWO}_{tc}$	*		°	°	°
joint sign.**WTA_ICS**					
DW-Statistic	0.49	1.73		1.62	
$\tilde{\rho}$		0.63	0.56	0.24	0.39
Prob $> \chi^2$	0.00	0.00	0.00	0.00	0.00

[a] Method: OLS (1), FGLS: Prais-Winsten with AR(1) correction (2,4,5), random effects panel (3), significance: ° (10%), * (5%), ** (1%). The upper and lower 5%–percentiles of the productivity distribution have been exempted from the analysis.

4. Conclusions

This paper has analyzed existence and effects of specific regimes of work organization. First, two alternative theoretical approaches that derive complementarities within

systems of work organizations are discussed. They lead to an integrated model, which predicts the existence of discrete equilibria of work organizations. These equilibria describe a hierarchy of systems. Firms with incompletely specialized workers and decentralized decision making are on the top layer. Moreover, this system hierarchy translates into a rank ordering of profits.

On a second stage, the theoretical hypotheses have been investigated empirically. The empirical results are rather tentative. First, increasing incidence of complementary systems of work organization that emphasize multitasking and participation in decision making is observed. Moreover, the duration of product cycles in firms that are assigned to multitasking is in fact shorter. In an econometric framework, a positive equilibrium shift in labor productivity is estimated and substantial factor embodied effects are observed.

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