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Hierarchical Structure in Brazilian Industrial Firms: an Econometric Study*

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Abstract

The paper investigates different implications of theoretical models for hierarchical structure. A sample of 6567 firms in the Brazilian manufacturing industry is considered and explanatory factors pertaining structural characteristics, network technology, technological innovations, managerial innovations and Incentive mechanisms are investigated. Despite the broader availability of explanatory variables in some categories, one only detects important joint effects accruing from the group of network technology variables as had been previously obtained in the related literature. In contrast, however, one can detect a marginally significant joint effect of the newly considered group of incentive mechanisms variables. The evidence in terms of individual effects is largely consistent with the predicted effects from the theoretical literature on hierarchy.

JEL Classification: C25, L22

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1. Introduction

Traditional microeconomic analysis often considers the firm as a black box identified with a production function. The growing complexity of firms operating in very dynamic markets renders the investigation of different aspects of the organization of firms as especially relevant.

A central issue with regard to the economics of internal organization of the firms [see Hölmstrom and Tirole (1989) and Milgrom and Roberts (1992) for extensive surveys], refers to the hierarchical design. That structural feature - the hierarchy, its levels, the span of control of managers and superiors - conditions, to a great extent, the performance of firms. Reflects also the range of job opportunities and allocation of workers, as well as the spectrum of wage differentials. More generally, it is a conditioning factor for the implementation of different decentralization practices that aim at avoiding coordination failures [see e.g. McAfee and McMillan (1998) and Lindbeck and Snower (2000)]. Equally important, the shape of the hierarchies evolves and can also be the direct or indirect result of strategic choices of organizations [see De Fraja (2004), and Yanes, Ng, Tang, Beard, (2005), henceforth YNTB (2005)]. More than a decade ago, Radner (1992) proposed that the study of the issues involved in hierarchical organization of firms could be categorized according to two main approaches. In the *decentralization of information* strand, the economic literature explores the way optimal hierarchies minimize the costs of information processing and communication [e.g. Keren and Levhari (1979), Radner, op.cit., Bolton and Dewatripont (1994)]. The *decentralization of incentives* approach is based on agency and contract theory (especially multi-agent moral hazard models) after the pioneering work of Williamson (1967) on hierarchies and loss of control. Other important references related to this rapidly growing literature can be obtained in Bolton and Dewatripont (2005, chapter 8 and part IV).

On the other hand, in the empirical literature only a handful of papers have emerged in terms of reduced form econometric studies. Delmastro (2002) investigated the determinants of management hierarchy taking as reference a sample of Italian manufacturing plants. The study considered variables related to size, production technology, network technology, managerial innovation, ownership status and industry characteristics. The evidence was generally consistent with the comparative statics' signs expected from theory, though those implied predictions are not always clear cut. In a related study based on the same data source, Colombo and Delmastro (2004), investigated the determinants of the delegation of authority. The evidence indicated that the complexity of plants' operations and organizations, the characteristics of communication technologies in use, the ownership status and the product mix of the parent companies are particularly relevant in explaining the delegation of decision power.

In the present paper, we intend to further investigate the scarcely studied topic on the explanatory factors affecting the management hierarchy. The study is undertaken for industrial firms in Brazil and one can highlight some motivating aspects that delineate the contribution of the paper, which are: (a) The consideration of a large developing economy with an industrial sector characterized by the co-existence of modern and traditional segments. Indeed, an eventual significant role for family-run firms can lead to non-economic departures from optimal hierarchical structures in addition to those pertaining state ownership. The heterogeneity of the Brazilian industry can provide an interesting environment for analysis; (b) The availability of a large and unique data base that allows to further explore the role of modern organizational practices and some forms of incentive mechanisms that are likely to reduce the need of worker monitoring; and (c) An interval measurement for the number of hierarchical levels that enables the consideration of econometric methods for count data instead of the potentially limiting ordinal level of measurement previously considered.

The paper is organized as follows. The second section discusses conceptual aspects that can clarify the determination of the hierarchical structure of a firm. The third section discusses the data and presents the empirical results associated with the empirical model. The fourth section brings some final comments.

2. Management hierarchy: conceptual aspects

As we suggested in the Introduction, despite the growing concern of the economics literature with the main object of our study, we are still far away from a structural empirical model of hierarchies. Consequently, and taking also into consideration the great technical sophistication of the pertinent models, there is a need to collect and organize some relevant approaches and predictions that can be helpful to the following empirical exercise (Section 3).

The starting point of our brief survey will be the seminal paper of Williamson (1967), which is extended and carefully examined by Calvo and Wellisz (1978,1979), Qian (1994), Martin (1993) and Bolton and Dewatripont (2005). One of the main purposes of Williamson´s treatment is to examine the relationship between the decisions taken by bounded rational managers and firm´s hierarchical structure. He (see also Martin *op.cit.*) takes into consideration a firm with *height* m in terms of the number of layers in the firm, denotes by s the *span of control*, that refers to the number of employees associated to each supervisor, and by α the *control loss* parameter that does not vary with the layer. Qian, *op.cit.* assumes that α declines down the layers, and the α_h are the object of choices by supervisors/employees. Therefore, firm output Y can be specified by $Y = \theta\ (\alpha s)^{m-1}$, being θ an average productivity parameter, α in the top layer is equal to 1, and

s^{m-1} denotes the layer of workers where production takes place. Naturally, as stressed by that author, the benefit of fewer levels is associated to smaller cumulative losses across the hierarchy, and its costs are related to (i) the reduced effectiveness of monitoring/supervision as the result of increased span of control, and (ii) the higher efficiency wages needed to induce employees to work (see below). The results that follow are worked out (with different emphasis) by the authors cited above, but at the cost of some simplification we will put them in the form of summarizing *propositions*, that are:

Proposition 1 (Williamson, Martin): In a competitive setting, with price-taking firms the profit maximizing value of m, the number of layers, rises as the profitability in relation to wages rise and as the control loss parameter α rises.

Proposition 2 (Williamson, Martin, Qian): In a competitive setting, the profit maximizing value of m raises with s, the number of employees associated to a given supervisor. More generally, the number of layers rises with (profitability) and scale, given by the number of workers in the lowest layer.

At this point some brief comments should be made about the costs incurred by the hierarchy. In fact, for Williamson, s does not vary along the levels, nor α, but it is not difficult to relax these assumptions to follow recent traditions. Following Bolton and Dewatripont, *op.cit.*, we could take s^{m-1} to be equal to N, and s indexed by the level such that s_h would equal the number of employees at level h + 1 divided by the number of employees at level h. Take φ to be an increasing function in effort α_h with α in the first level equal to one (the principal does not incur in loss of control). With a two layers hierarchy, it can be shown that the efficiency wage that would give incentives to employees at the bottom layer not to shirk would be equal to $w_1 = \varphi(\alpha_1) N$. With a three layers hierarchy, $w_2 = \varphi(\alpha_2) N/s_h$, which means that a lower wage would be paid to lower levels employees, what is in accordance with one of Williamson`s assumptions (see Martin, *op.cit.*). That is, when the principal gets more supervisors, he reduces his span of control, the loss of control and the wage per supervisor in the intermediate layers, having however to pay more to supervisors to avoid them to shirk. This wage inequality structure is a general result that emanates from the body of literature we are examining. However, the lack of appropriate information in our data base recommends that we go to the next *proposition*, which follows:

Proposition 3 (Martin, McAfee and McMillan): In an oligopolistic setting, where firm structure is also treated as endogenous, the number of hierarchical layers decrease as the number of firms increase. That is, the number of layers would increase with concentration.

This proposition also suggests that a firm with a long hierarchy may not survive more competitive pressures in output market. One of the reasons for this prediction is that (see McAfee and McMillan, *op.cit.*, for extensions and related literature on *influence costs*) private information in lower levels and the associated bargaining power of middle-range managers result in diseconomies of scale ("Rents must exist for a long hierarchy to be viable").

In a recent study, YNTB (2005), explored the endogenous determination of firm structure. Even in a competitive setting, firms could insert the hierarchy as an argument of the production function. That is, the organization of the hierarchy determines output. Firm inputs are measured in terms of the height of he hierarchy (its vertical dimension) and the span of control (in a CES production function) assuming that workers at different levels perform different tasks, in such a way that an increase in the elasticity of substitution corresponds to a decrease in task specialization - decrease in intra-firm specialization - division of labor occurs in a lesser extent. In particular, technologically intensive sectors are characterized by high intra-firm specialization. The study lead us, among other important results, to the following *propositions*:

Proposition 1` (YNTB): When tasks are segmented by levels, the firms will expand both vertically and horizontally when output price rises. And,

Proposition 4 (YNTB): When tasks are segmented by levels, the firms tend to become less hierarchical as intra-firm specialization declines. More specifically, technologically intensive sectors are expected to be more hierarchical than sectors where intra-firm specialization is low.

Given the heterogeneous nature of our data base (see Introduction), those conjectures may be subjected to some qualifications that are, it should be stressed, explicitly beyond the scope of YNTB paper. Based on extensive empirical literature, Lindbeck and Snower (2000), LS, [see also Milgrom and Roberts (1990)] take us to the realm of evolving organizational forms, and to the role of multi-task learning on the reorganization of work. In fact, one of their key concepts is that of “blurring of occupational boundaries”, which encompasses capital deepening and capital widening. When workers are allowed to acquire more skills and variety of skills, newer forms of organization tend to promote multi-task learning, the complementarities among tasks and the decentralization of decision making. Our summary device may be applicable, and an additional proposition follows:

Proposition 5 (LS): Managerial innovations (for example, Total Quality Management, Just-in-Time) promote the learning across tasks, and the decentralization of decision making where employees perform a wider variety of tasks .

This proposition is supported by the analysis of Keren and Levhari (1979) and Bolton and Dewatripont (1994), and allow us to qualify the puzzle properly stressed by Delmastro (2002), who confronts these points of view with that of Lazear (1995), who predicts that reductions in the cost of communication promote specialization and hierarchy. Our reconciling reading, based on *proposition 4*, is that declines in communication costs would tend to promote both specialization of workers in *specific tasks* and (when this is the case) the reliance on large hierarchies. However, we think that the point deserves a particular *proposition*, that follows:

Proposition 6 (Delmastro): Advances in intra-firm communication increase the likelihood of a plant choosing a multi-layered structure, and improvements in inter-firm communication decrease this probability.

Following Lindbeck and Snower, *op.cit.*, Hölmstrom and Milgrom (1994), McAfee and McMillan, *op.cit.*, and Delmastro (2002), we will now make explicit our final *proposition*, that gives a link to previous comments.

Proposition 7 (LS): The introduction of computerized information and communications systems is associated to the decentralization of decision making, to team work, job rotation and multitasking, leading supervision to be more closely tied to ex-post performance. In particular, corporate reorganizations pushed by competitive pressures make pay to be more closely related to performance.

Altogether, the results just summarized enable to have a better notion on the possible expected signs of the coefficients of the reduced form model considered in section 3.2.

3. Empirical analysis

3.1- Data construction

The present study relied on a comprehensive survey carried out by Fundação SEADE for industrial firms in the state of São Paulo [Pesquisa da Atividade Econômica Paulista-PAEP] in 1996. This survey comprised some basic accounting data, but more importantly detailed data on technology and organizational practices. The final sample after verifying for omissions has 6567 observations. Next, we describe the variables considered in this study, classified by large categories:[1]

. HIE: number of hierarchical levels in the firm;

Structural characteristics

. SIZE: total number of employees;

. CONC: industrial concentration as measured by the Herfindahl index at the 4-digits level (HH = $\sum_i s_i^2$, where s_i stands for the market share of the i-th firm in a given sector),

1 Unlike Delmastro (2002), we did not have access to information on ownership status. Nevertheless in the year of 1996 the only Brazilian industrial sector with important state participation in production was oil refining that was excluded from our sample.

Managerial innovations

. TQM: assumes value 1 if the firm adopts total quality management, and 0 otherwise;

. JIT: assumes value 1 if the firm either adopts internal just-in-time or external just-in-time, and 0 otherwise;

. KAIZEN: assumes value 1 if the firm adopts improvement groups practices, and 0 otherwise. Those practices had been defined as a new production philosophy integrated to TQM programs and is based in the introduction of continuous and permanent improvements in the production processes;

. SCP: assumes value 1 if the firm adopts statistical control of processes, and 0 otherwise. It is believed that SCPs preceded the adoption of TQM in Brazilian firms (see below).

Technological innovation

. INOV: assumes value 1 if the firm made significant or incremental innovations in processes and/or in products between 1994-1996;

. R&D: number of employees allocated to R&D activities divided by the total number of employees;

. IM: import intensity defined by imports divided by apparent consumption, as provided at the 3-digits level [source: Moreira (1999)]. In fact, capital goods imports after Brazilian trade liberalization is reputed to have important modernization effects in different industrial sectors.

Network technology

. MICRO: number of microcomputer per employee;

. INTER: assumes value 1 if the firm has access to the Internet and 0 otherwise;

. INTRA: assumes value 1 if the firm has access to local exchange networks (e.g. LAN networks) and 0 otherwise;

Incentive mechanisms

. PSHAR: assumes value 1 if there exists a profit sharing mechanisms for employees and 0 otherwise;

. TRAIN: assumes value 1 when the firm offered courses in managing techniques, total quality control methods and in languages to blue collar workers.

The summary statistics of the different variables are presented in table 1 and indicate a significant degree of heterogeneity in the sample.

INSERT TABLE 1 AROUND HERE

3.2- Empirical results

The main results from the econometric estimates are presented in tables 2. For completeness, we also present the results related to the ordinary least squares estimation, though the discrete nature of the dependent variable is better approached by means of count data models. Moreover, unlike previous evidence that had to rely on data with ordinal features, we can fully take advantage of count data models in the present study. [2]

INSERT TABLE 2 AROUND HERE

The most traditional model in the context of count data is the Poisson model, where the (conditional) probability mass function of y given x is provided by:

[2] Cameron and Trivedi (1998) provide a comprehensive overview of econometric methods for count data models. Wooldridge (2002, 2003) are also important references.

$$\Pr\langle Y_i = y_i \,|\, x_i \rangle = \frac{e^{-\mu_i}\mu_i^{y_i}}{y_i!} \qquad for \quad y_i = 0,1,2... \qquad (1)$$

Further, as usual, one considers a link to explanatory variables as given by $\ln(\mu_i) = x_i^{'}\beta$, where x is the vector of characteristics and β the vector of parameters. However, that model embodies the potentially limiting assumption of the mean being equal to the variance, that is, $\mathrm{var}(y/x) = E(y/x) =$ μ_I = exp($x_i^{'}\beta$), an assumption that is often violated in applied works. In that sense, the estimation of the Poisson model is a possibly preliminary step in the analysis as the consideration of an overdispersion test is warranted. A possible test is advanced by Cameron and Trivedi (1998, p. 78, eq. 3.39). The test requires the estimation of the Poisson model to generate fitted values [$\hat{\mu}_i = \exp(x_i^{'}\hat{\beta})$] to be used in the auxiliary ordinary least squares regression of the form:

$$\frac{(y_i - \hat{\mu}_i)^2 - y_i}{\hat{\mu}_i} = \alpha\,\hat{\mu}_i + u_i \qquad (2)$$

where u_i is the error term. The t statistic corresponding to the α coefficient possesses an asymptotically normal distribution under the null hypothesis of no overdispersion. In the present application, the evidence clearly favors the rejection of the null hypothesis and therefore the plausibility of the Poisson model. In fact, the corresponding statistic was 724.74 [with p-value = 0.000].

Given that result, we could go on and use Poisson Quasi Maximum Likelihood estimation, PQMLE, not assuming that the Poisson distribution is correct in its entirety [see Wooldridge (2002, 2003), chapters 19 and 17, respectively]. This is a procedure that recommends adjustments in the standard errors when Var (y|x) = σ^2 E (y|x) is assumed. Instead, we proceed with the estimation of a negative binomial model – NB, that essentially implies the inclusion of an individual, unobserved effect into the conditional mean [see e.g. Cameron and Trivedi (1998), chaps. 2 and 3] [3]. The NB distribution will constitute our preferred specification and indeed it is reputed to have good robustness properties against misspecification in the case of overdispersion. In this case, model NB II of Cameron and Trivedi, *op.cit..* guarantees that two moment conditions will hold, as follows:

$$\mathrm{var}(y/x) = E(y/x) = \mu_i \text{ and } w_i = \mu_i + \alpha\mu_i^2 \qquad (3)$$

The parameters μ and β can be jointly estimated. When μ is estimated in a first-stage, as we did, β can be estimated by maximizing the log-likelihood function for all observations, with respect to β. The resulting Quasi Maximum Likelihood Estimator – QMLE [that Gourieroux, Monfort and Trognon (1984), and Cameron and Trivedi, *op.cit.*, p.33, call *quasigeneralized peudomaximum likelihood*] guarantees that the estimator for β is fully efficient [see Cameron and Trivedi, op.cit., p.73) and the important result that the first-stage estimation of μ can be ignored [see Wooldridge (2000), pp. 355, 658-659] given only the conditional mean assumption.

Before proceeding with the description of the results it is important to emphasize that the conditional mean of the negative binomial is the same as the Poisson model whereas the conditional variance differs across those models. Therefore, the marginal effects can be computed in both cases as $\frac{\partial E\langle y_i | x_i \rangle}{\partial x_i} = \mu_i \beta = e^{x_i' \beta}\beta$, which are considered for our preferred specification with

[3] The alternative hypothesis of that overdispersion test considers the alternative in terms of negative binomial model (NB2) model of Cameron and Trivedi with variance function given by $w_i = \mu_i + \alpha\mu_i^2$. All estimations were undertaken with the software Eviews 5.0.

explanatory variables at the mean sample values so as obtain a better perspective on the magnitude of the effects.

It is interesting to observe that for different significant coefficients the magnitude and signs were remarkably similar in the two specifications. Exceptions, however, occur for some organizational practices' variables. From a more specific statistical point of view the results are appealing. There is a good overall fit as indicated by the coefficient of determination and a broad range of significant coefficients with meaningful signs. Therefore, we think that those with more meaningful coefficients should be associated to our *propositions*.

Propositions 1/1` constitute general references that cannot be directly highlighted by the results, but that is not the case with respect to *Propositions 2* and *3*. In fact, the number of hierarchical levels increases with size, though no significant effect for concentration is detected, what gives a partial and indirect support to the initial *propositions*. Note, however, that the marginal effect of SIZE is very small.

Proposition 4 deserves a special attention, as it suggests that technology intensive sectors tend to become more hierarchical. In the present study its empirical counterpart lies in the coefficients of IM, INOV and R&D. The INOV indicator has very low marginal effect and indicates a negative effect on the number of hierarchical levels of Brazilian firms, but that is not the case when IM and R&D are considered. In both cases the positive coefficient is significant, and the marginal effect of R&D reached 7.220.

Proposition 6 is strongly supported by the results related to MICRO, INTER and INTRA, as far as the signs of the coefficients are concerned. They all indicate (with highly significant coefficients) that the introduction of micro-computers and inter-firm communications systems contribute to the decrease of hierarchical levels, but that the introduction of intra-firm communications systems tends to lead to more hierarchy, where the marginal effect of INTRA reaches the expressive value of 2.300.

A partial compatibility occurs between *proposition 5* and our managerial innovations variables. The coefficient of the variable TQM appears with the expected sign, but with no significant effect detected. It is worth mentioning the significant negative effects emerging from SCP and KAIZEN that would be consistent with the reasoning by LS. In the case of JIT (a variable that includes internal as well as external just-in-time), however, one obtains a positive and significant coefficient[4]. Among these variables, it should be emphasized, SCP revealed the most expressive marginal effect.

Finally, TRAIN, that we take as an indicator of incentive mechanism and of multi-tasking improvements, and our indicator of profit sharing with employees, PSHA, exhibit expected signs in the light of *proposition 7*, and their marginal effects are also non-negligible and indicate the expected negative effect on the number of hierarchical levels.

Despite individual significant effects, it is important to have a sharper portrayal of the hierarchical structure by considering the impact of selected categories of explanatory factors. For that purpose, we consider likelihood ratio type tests for different groups that are partially similar to those considered by Delmastro (2002) and are reported in table 3.

INSERT TABLE 3 AROUND HERE

[4] Professor David Kupfer pointed up to us that it is a well known fact that at the date our information was collected the Brazilian industry was just introducing Total Quality Methods, and that the statistical control methods preceded the more broadly adoption of TQM.

First, we consider a group of structural variables (comprising both firm and sectoral level data). Unlike the aforementioned author, this group included a firm-level structural variable as given by the firm size and concentration. The evidence indicated that as a group the referred variables play no significant role.

The group referring to technological innovation comprised variables that can be seen as an input to the innovative activity (R&D) or an output of the process (INOV). The joint effects of those variables are statistically negligible. Analogous results were previously obtained in the context of production technology variables related to production flexibility and the degree of automation.

In the group of managerial innovations, we considered not only more traditional practices like total quality management (TQM) and just-in-time (JIT) but also improvement groups (KAIZEN) and statistical control of processes (SCP). Nevertheless, the previous evidence seems to prevail: there are no relevant effects of modern organization practices as a group in explaining hierarchical structure.

In the group of network technology, we include in addition to the Internet (INTER) and Intranet (INTRA) access variables previously considered in the literature, a variable indicating the availability of microcomputers relative to the number of employees (MICRO). In fact, the actual utilization of the network presupposes an adequate access to IT equipments. In this case the evidence is very strong in the sense of indicating a strong joint effect of those variables in explaining hierarchical structure and once more is consistent with the previous evidence.

An additional category included in this study refers to incentive mechanisms that can mitigate the need for closer monitoring. In that category, we included a more indirect element as given by training to personnel not related to production (TRAIN) and a direct factor referring to the prevalence of profit sharing with employees (PSHA). The evidence with that respect is partially encouraging, as those variables are marginally significant as a group.

4. Final comments

The paper undertook an econometric investigation on the determinants of the hierarchical structure in Brazilian manufacturing industry in 1996. In broad terms one can highlight categories of explanatory factors relating to structural characteristics, network technology, technological innovations, managerial innovations and Incentive mechanisms. Among those, one only detects strong joint effects accruing from network technology variables as was the case in the previous literature. When we take these variables individually, a strong tendency to more hierarchical levels is detected, together with some consistent indications of decentralization. In fact, a marginally significant joint effect is associated with the group of newly considered incentive mechanisms variables. Taken individually, these last variables point in the direction of more decentralized structures in Brazilian industry firms.

As a whole, the analysis of the effects associated with individual variables was largely consistent with theoretical predictions from the hierarchy literature. Nevertheless, different routes for future research appear to be relevant. First, the reduced form character of the analysis should be followed at some stage by structural econometric investigations that are yet absent in this particular context. In particular, the data used in the present study was not updated. Second, the assessment of complementarities among the different organizational practices and incentive schemes is a topic of related interest that is in the front line of the literature of Industrial Organization.

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Table 1

Summary Statistics (No. of observations: 6567)

Variables	Minimum	Maximum	Mean	Std. deviation
HIE	2.00	10.00	3.46	1.61
SIZE	2.00	20159.00	166.84	637.96
CONC	0.00	1.00	0.16	0.17
IM	0.00	0.82	0.19	0.24
INOV	0.00	1.00	0.81	0.39
R&D	0.00	0.23	1.59E-03	0.01
MICRO	0.00	2.50	0.11	0.14
INTRA	0.00	1.00	0.45	0.50
INTER	0.00	1.00	0.87	0.33
TQM	0.00	1.00	0.61	0.49
JIT	0.00	1.00	0.89	0.31
KAIZEN	0.00	1.00	0.82	0.39
SCP	0.00	1.00	0.60	0.49
PSHA	0.00	1.00	0.69	0.46
TRAIN	0.00	1.00	0.78	0.41

Table 2: Determinants of Hierarchical Structure – Econometric Estimates (No. of observations: 6567)

Variables	Ordinary least squares	Poisson model	Negative binomial model	
Constant	2.865 (0.000)	1.040 (0.000)	1.018 (0.000)	3.320
SIZE	1.08E-04 (0.000)	1.99E-05 (0.000)	2.41E-05 (0.000)	7.86E-05
CONC	0.023 (0.778)	0.816E-02 (0.724)	0.003 (0. 866)	0.010
IM	0.402 (0.000)	0.116 (0.000)	0.114 (0.000)	0.372
INOV	-0.065 (0.052)	-0.0232 (0.024)	-0.019 (0.026)	-0.062
R&D	8.705 (0.003)	1.819 (0.002)	2.213 (0.000)	7.220
MICRO	-0.565 (0.000)	-0.207 (0.000)	-0.141 (0.000)	-0.460
INTRA	2.425 (0.000)	0.712 (0.000)	0.706 (0.000)	2.300
INTER	-0.071 (0.015)	-0.0310 (0.002)	-0.029 (0.001)	-0.095
TQM	-0.065 (0.050)	-0.018 (0.069)	-0.012 (0.142)	-0.039
JIT	0.061 (0.137)	0.0191 (0.131)	0.021 (0.045)	0.068
KAIZEN	-0.059 (0.103)	-0.022 (0.045)	-0.022 (0.014)	-0.072
SCP	-0.207 (0.000)	-0.060 (0.000)	-0.053 (0.000)	-0.173
PSHA	-0.133 (0.000)	-0.041 (0.000)	-0.040 (0.000)	-0.130
TRAIN	-0.226 (0.000)	-0.079 (0.000)	-0.074 (0.000)	-0.241
Adjusted R^2	0.534	0.543	0.540	
Log likelihood	-9919.86	-10833	-15297.56	

Note: p-vales are indicated in parentheses where the related standard errors are robust to heteroskedasticity; Poisson model was estimated by maximum likelihood, Negative Binomial model was estimated by quasi-maximum likelihood with the last column in the right presenting the marginal effects (that can be compared to the OLS coefficients).

Table 3: Determinants of hierarchy-joint significance tests for selected categories of explanatory variables

Group of variables	**Test statistic**	**p-value**
Technological innovations		
R&D, INOV, IM	$\chi^2(2) = 5.501$	0.139
Managerial innovations		
TQM, JIT, KAI, SCP	$\chi^2(4) = 4.394$	0.355
Network technology		
INTRA, INTER, MICRO	$\chi^2(3) = 515.151$	0.000
Incentive mechanisms		
PSHA, TRAIN	$\chi^2(2) = 5.668$	0.0587
Structural characteristics		
SIZE, CONC	$\chi^2(3) = 1.224$	0.542