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 6578 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. Important joint effects are detected for all groups of variables in partial contrast with the related previous literature. Moreover, one detects 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.

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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), where the authors entertain the themes of the choice of institutions, the design of decision-making rules and the allocation of control rights [see also Hart and Moore (2005)].

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 a panel data study, Rajan and Wulf (2003) found evidence that organizations are becoming flatter, with authority being pushed down the hierarchy.

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 *expected results*, being the first two of them reference conjectures, that are:

Expected Result **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.

*Expected Result **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. It is important to stress that the size of the firm is directly associated to s and therefore a positive expected effect on hierarchy accruing from firm size naturally emerges. However, the lack of appropriate information in our data base recommends that we go to the next *proposition*, which follows:

*Expected Result **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 *result*:

Expected Result **4** (YNTB): When tasks are segmented by levels, the firms tend to become less hierarchical as intra-firm specialization declines, and the firms will expand both vertically and horizontally when output price rises. 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. If we interpret, as the authors and Hart & Moore (2005) do, the decentralized organization as the one where it is likely that a decision will be made by a specialist rather than by a coordinator, our summary device may be applicable, and an additional proposition follows:

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

This proposition supported and amplified by the analysis of Keren and Levhari (1979), Bolton and Dewatripont (1994), who point out that advances in communication technology lead to flatter organizations. *Expected Results* 4 and 5 and the previous comments also 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 costs of communication promote specialization and hierarchy (layers are associated to tasks). Our reconciling reading, is that when declines in communication costs tend to promote both specialization of workers in *specific tasks* the reliance on large hierarchies follows.

But when multitasks are fostered, flatter hierarchies are to be expected. We think that the point deserves a particular *proposition*, that follows:

Expected Result **6** (KL, BD): Reductions in the costs of communications (intra-firm and inter-firm) reduce the likelihood of a plant choosing a multi-layered structure.

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.

Expected Result 7 (LS, MM): 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 basic data source of the study is the extended survey carried out by Fundação SEADE for firms in the state of São Paulo [Pesquisa de Atividade Econômica Paulista-PAEP]. Even though, data is essentially available in terms of a cross-section for 1996 (with the exception of a few variables), it is worth mentioning the wealth of information in terms of organizational practices. That kind of information is rarely available and the same occurs with the advertising data

used in this study. Our sample includes 6578 manufacturing firms classified at the 4-digits level after considering some omissions. This survey has mostly a census character as that was the case with firms in São Paulo with headquarters in that state. For firms with headquarters situated outside the state a sampling procedure is undertaken for firms with at least 30 employees. In order to implement the survey Fundação SEADE considered list of firms from the Brazilian bureau of statistics [IBGE] and administrative reports from the Ministry of Employment and Labor{Relação Annual de Informações Sociais-RAIS]. The former source is a comprehensive and reliable source for the existent firms as any formal enterprise is required to report basic information regarding employment and educational level of employees unless one is willing to pay heavy fines. It is important also to stress that the segment of the sample that possesses a census character is highly dominant in the case of the industry questionnaire of the PAEP. In fact, the firms with headquarters in the state of São Paulo are responsible for 81.5 % of the employment of all firms established in that state according to IBGE. Finally it is worth mentioning the importance of the manufacturing industry in São Paulo with respect to Brazil. Taking as reference information from IBGE [Pesquisa Industrial Annual-PIA-IBGE] one can indicate in 1996 a participation of 51.57% relative to the total of Brazilian manufacturing industry when the criterion is values added. When one considers total employment, the relevant figure is 48.71 %. The previous comments indicate that, despite the sampling procedure present in part of the survey, the present data base appears to be representative of the manufacturing industry.

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),

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, 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).

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.

Technological innovation

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

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.

Table 1
Summary Statistics (No. of observations: 6578)

Variables	Minimum	Maximum	Mean	Std. deviation
HIE	1.00	10.00	3.22	1.75
SIZE	1.00	20159.00	168.49	654.10
CONC	0.00	1.00	0.16	0.17
R&D	0.00	0.23	1.58E-03	7.08E-03
MICRO	0.00	1.00	0.11	0.11
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	0.75	0.43
KAIZEN	0.00	1.00	0.81	0.39
SCP	0.00	1.00	0.60	0.49
PSHA	0.00	1.00	0.68	0.46
TRAIN	0.00	1.00	0.94	0.23

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] Examples of applications include the number of visits to doctors and to recreational facilities. Applications in the context of Industrial Organization are relatively uncommon and are exemplified by the work of Hausman et al (1984)

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, $\text{var}(y/x) = E(y/x) = \mu_i = \exp(x_i'\beta)$, 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. The Negative Binomial - NB model is a more general model that allows to test the significance of the overdispersion parameter α, made explicit below. For the NB model as in that more general framework one has:

$$E\langle y \,|\, x \rangle = \mu_i \quad \text{and} \quad Var\langle y \,|\, x \rangle = \mu_i + \alpha\mu_i^2 \qquad (2)$$

Even though count data models acknowledge the discrete nature of the dependent variable, often more specialized models are required. In fact, zero truncation often arises in different contexts. In the present study on the determinants of hierarchy truncation at zero is clearly an issue. The conditional density function for a left -truncated model is given by:

$$f\langle y_i; \mu_i \,|\, y_i \geq r \rangle = \frac{h(y_i;\mu_i)}{1 - H(r-1;\mu_i)} \qquad y_i = r, r+1.... \qquad (3)$$

where h(.) stands for the untruncated distribution whereas H(.) refers to the related cumulative distribution. The choice of Poisson or Negative Binomial specification for h(.) would define the particular truncated count model under consideration and of course r=1 in our particular application.

The results are presented in table 2 and all estimations were implemented with Stata 9.2. It is interesting to observe that the estimates for the zero truncated

negative binomial-ZTNB and the zero truncated Poisson-ZTP were identical. In fact, the negligible value of the overdispersion parameter provides a strong support for considering the referred truncated Poisson model as the preferential specification as the estimation of the ZTNB model led to α = 1.50E-07. Gurmu (1991) and Gurmu and Trivedi (1992) had advanced tests for overdispersion in the context of truncated count data models. A difficulty was related to the non-validity of standard regularity conditions of maximum likelihood estimators at the boundary of the parameter space. In that sense, the software Stata considers an adjusted likelihood ratio test for α = 0 as suggested by Gutierrez et al (2001). This modified test statistic is distributed a 50:50 mixture of a χ_0^2 (point mass at zero) and a χ_1^2. In the present application one could not reject the null hypothesis of α = 0 and therefore we confidently consider the ZTP model as that adjusted test statistic was $\overline{\chi_{01}^2}$ = 5.4E-05 with p-value = 0.497.

Table 2: Determinants of Hierarchical Structure – Econometric Estimates (No. of observations: 6578)

Variables	**Ordinary least squares**	**Zero truncated Poisson model**
Constant	4.515 (0.000)	1.562 (0.000)
SIZE	2.38E-04 (0.000)	3.82E-05 (0.000)
CONC	0.232 (0.059)	0.091 (0.038)
R&D	17.116 (0.000)	3.984 (0.000)
MICRO	-1.162 (0.000)	-0.450 (0.000)
INTRA	-0.616 (0.000)	-0.249 (0.000)
INTER	-0.239 (0.001)	-0.078 (0.000)
TQM	-0.105 (0.040)	-0.041 (0.026)
JIT	-0.001 (0.979)	-3.48E-04 (0.985)
KAIZEN	-0.183 (0.004)	-0.058 (0.003)
SCP	-0.362 (0.000)	-0.134 (0.000)
PSHA	-0.315 (0.000)	-0.112 (0.000)
TRAIN	-0.146 (0.122)	-0.040 (0.141)
	Adj R^2 = 0.131	Wald $\chi^2(12)$ = 1010.30 (0.000)

Note: p-vales are indicated in parentheses where the related standard errors are robust to heteroskedasticity; Poisson model was estimated by maximum likelihood

The evidence is to a great extent consistent with the previously advanced theoretical results. 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 *expected results*. Our *results* follow:

Expected Result 1 constitutes general reference that cannot be directly highlighted by the results. That is not the case with *expected results* 2 and 3. Results 2 and 3 point out that the number of hierarchical levels increases with size and concentration.

Result 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 coefficient of R&D. The referred coefficient is in fact positive and statistically significant.

A partial compatibility occurs between *expected result 5* and our managerial innovations variables. It is worth mentioning the significant negative effects emerging from TQM, SCP and KAIZEN that would be consistent with the reasoning by LS. In the case of JIT (a variable that includes internal just-in-time), however, one obtains also a negative but in that case non significant coefficient[3].

Expected Result 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-

[3] 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.

computers, intra-firm and inter-firm communications systems contribute to the decrease of hierarchical levels.

Finally, the support for the role of incentive mechanisms is partial. TRAIN, that we take as an indicator of incentive mechanism and of multi-tasking improvements exhibits a negative but non significant coefficient whereas our indicator of profit sharing with employees, PSHA, exhibits expected negative sign in the light of *expected result 7*.

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 Wald type tests for different groups that are partially similar to those considered by Delmastro (2002) and are reported in table 3.

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

Group of variables	**Test statistic**	**p-value**
Managerial innovations		
TQM, JIT, KAI, SCP	$\chi^2(4) = 123.61$	0.000
Network technology		
INTRA, INTER, MICRO	$\chi^2(3) = 254.28$	0.000
Incentive mechanisms		
PSHA, TRAIN	$\chi^2(2) = 51.51$	0.000
Structural characteristics		
SIZE, CONC	$\chi^2(2) = 34.16$	0.000

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 do play a significant role.

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, in contrast with the previous evidence, there are 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 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 encouraging, as those variables are 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. All those, indeed exerted a significant joint effect in explaining hierarchical levels. The results are therefore stronger than those in the previous related literature. If one considers the variables individually, a strong tendency to more hierarchical levels is detected, together with some consistent indications of decentralization and fewer hierarchical layers. Moreover, a 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.

References

Bolton, P., Dewatripont, M., (1994), The Firm as a Communication Network, *Quarterly Journal of Economics*, 109, 809-840;

Bolton, P., Dewatripont, M., (2005), *Contract Theory*, Cambridge-MA.: MIT Press;

Calvo, G., Wellisz, S. (1978), Supervision, Loss of Control and the Optimal Size of Firm, *Journal of Political Economy*, 86, 943-952;

Calvo, G., Wellisz, S. (1979), Hierarchy, Ability, and Income Distribution, *Journal of Political Economy*, 87, 991-1010;

Cameron, A.C., Trivedi, P.K. (1998), *Regression Analysis of Count Data*, Cambridge: Cambridge University Press;

Colombo, M., Delmastro, M. (2004), Delegation of Authority in Business Organizations: an Empirical Test, *Journal of Industrial Economics*, 52, 53-80;

De Fraja, G. (2004), Hierarchies in Organizations and Labour Market Competition, *Labour Economics*, 11, 669-686;

Delmastro, M. (2002), The Determinants of the Management Hierarchy: Evidence from Italian Plants, *International Journal of Industrial Organization*, 20, 119-37;

Delmastro, M. (2002), On the choice of incentives in firms: influence activity, monitoring technology and organizational structure, *Economics Bulletin*, 12, 1-13;

Greene, W.E. (2003), *Econometric Analysis*, Upper Saddle River-NJ: Prentice Hall, 5th edition;

Gurmu, S. (1991), Test for Detecting Overdispersion in the Positive Poisson Regression Model, *Journal of Business and Economics Statistics*, 9, 215-22;

Gurmu, S., Trivedi, P. (1992), Overdispersion Tests for Truncated Poisson Regression Models, *Journal of Econometrics*, 54, 347-70;

Gutierrez, R.G., Carter, S.L., Drukker, D.M. (2001), On Boundary-Value Likelihood- Ratio Tests, *Stata Technical Bulletin Reprints*, 10, 269-73;

Hausman, J., Hall, B., Griliches, Z. (1984), Econometric Models for Count Data to the Patents-R&D Relationship, *Econometrica*, 52, 909-938;

Hart, O., Moore, J. (2005), On the Design of Hierarchies: Coordination versus Specialization, *Journal of Political Economy*, 113, 675-702;

Hölmstrom, B., Tirole, J. (1989), The Theory of the Firm, In R. Schmalensee and R.D. Willig (eds.), *Handbook of Industrial Organization*, Amsterdam: North-Holland, 61-133;

Hölmstrom, B., Milgrom, P. (1994), The Firm as an Incentive System, *American Economic Review*, 84, 972-991;

Keren, M., Levhari, D. (1979), The Optimal Span of Control in a Pure Hierarchy, *Management Science*, 25, 1162-1172;

Lazear, E., (1995), *Personnel Economics*, Cambridge-MA.: MIT Press;

Lindbeck, A., Snower, D.J. (2000), Multitask Learning and the Reorganization of Work: From Tayloristic to Holistic Organization, *Journal of Labor Economics*, 18, 353-376;

Martin, S. (2002), *Advanced Industrial Economics*, Oxford: Blackwell Publishers, 2nd ed.;

McAfee, R.P., McMillan, J. (1998), Organizational Diseconomies of Scale, *Journal of Economics & Management Strategy*, 4, 399-426;

Milgrom, P., Roberts, J. (1990), The Economics of Modern Manufacturing: Technology, Strategy, and Organization, *American Economic Review*, 80, 511-528;

Milgrom, P., Roberts, J. (1992), *Economics, organizations, and management*, Englewood Cliffs, NJ: Prentice Hall;

Qian, Y. (1994), Incentives and Loss of Control in Optimal Hierarchy, *Review of Economic Studies*, 61, 527-544;

Radner, R. (1992), Hierarchy: the Economics of Managing, *Journal of Economic Literature*, 30, 1382-1415;

Rajan, R.G., Wulf, J. (2003), The Flattening Firm: Evidence from Panel Data on The Changing Nature of Corporate Hierarchies, Cambridge, MA: *National Bureau of Economic Research*, Working Paper 9633;

Wooldridge, J.M., (2002), *Econometric Analysis of Cross Section and Panel Data*, Cambridge-MA.: MIT Press;

Wooldridge, J.M., (2003), *Introductory Econometrics*, Thomson South-Western;

Williamson, O.E (1967), Hierarchical Control and Optimal Firm Size, *Journal of Political Economy*, 75, 123-138;

Yanes, L., Ng, E., Tang, K.K., Beard, R., (2005), The hierarchical structure of a firm: a geometrical approach, *Economics Bulletin*, 12, 1-7.

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