Testing Models of Hierarchy: Span of Control, Compensation and Career Dynamics

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Abstract

In this paper, we test implications from various theories of hierarchies in organizations, in particular the assignment model (Rosen, 1982), the incentives model (Rosen, 1986), the supervision model (Qian, 1994) and the knowledge-based hierarchy model (Garicano, 2000; Garicano and Rossi-Hansberg, 2006). We use a unique dataset providing personnel records from a large European firm in an high tech manufacturing industry from January 1997 to May 2004. An unusually rare feature of this dataset is that relationships within the hierarchy are reported and we can therefore identify the chain of command. Some of our results are in line with the Garicano and Rossi-Hansberg (2006) model of hierarchies when communication costs are decreasing: we observe an increase in the span, an increase in wage inequality between job levels, and the introduction of a new hierarchical level. However, we also find evidence of learning and reallocation of talent within and across job levels, a finding that can not be explained by a static model of knowledge based hierarchy but rather by dynamic models of careers in organizations (e.g. Gibbons and Waldman, 1999). We then propose a new model of hierarchies where individuals accumulate general and managerial human capital on the job, and firms learn gradually about individuals' managerial ability and allocate managers to span according to their expected effective ability. This theory explains our empirical findings and provides a richer theory of careers in hierarchies.

1 Introduction

The modern firm is typically organized internally as an hierarchy. Previous theoretical attempts to understand the *concept of hierarchy* have led to a large body of literature emphasizing different mechanisms and trade offs that firms faced[1]. Yet, there have been few attempts[2] to study this topic empirically, probably because data about hierarchical relationships are extremely hard to get. Despite the richness of firms' personnel records which have become increasingly available to researchers (see e.g. Gibbs and Hendricks, 2004 and the papers referenced therein), none of the existing datasets provide information about the chain of command and the span of control. This is a unique feature of our dataset that we are able to exploit for our analysis.

In this paper, we explore a brandnew dataset providing a clear description of the hierarchical structure and reporting relationships of a large European firm, and we investigate some key predictions from various theories of hierarchies. These theories in practice generate many similar results and testable predictions (a similar concern has been formulated when testing incentives theories, see e.g. Prendergast, 1999). Our main goal is to assess whether these theoretical predictions are verified in the data, but we also discuss attempts to distinguish between them.

We first discuss the large literature about hierarchies, emphasizing the differences between the various theories, and their empirical predictions. We distinguish between static theories of hierarchies - leaving aside careers in organizations - and dynamic theories of careers - leaving unmodelled implications for the span of control. We then propose a simple framework reconciling these two strands of the literature.

Turning to our empirical analysis, we document the evolution of the hierarchy and the evolution of the average span of control. The company has become flatter and the span of control for each layer has increased, in line with what happened in the U.S. over a longer time period (Rajan and Wulf, 2003). In a second step, we describe the evolution of the wage gap between job levels. We observe an increase in the wage gaps between levels, also in line with the evidence in Rajan and Wulf. We then test whether the span of

[1] See the next section for a detailed discussion of the literature.

[2] Exceptions are Ortín-Ángel and Salas-Fumás (2002) and Rajan and Wulff (2003) using survey data from top executives in different firms; and Garicano and Hubbard (2003, 2004) using census data from law firms. Again see next section.

control has an effect on managerial compensation and look at the evolution of the relationship. Several theories of hierarchies suggest a positive relationship between span and compensation and we try to distinguish between them. We also analyze the relationship between the size of the bonus and the number of subordinates, since firms should have more flexibility to reward supervision using bonuses rather than wages. We find that wages and bonuses are positively related to span of control, as implied by supervision models like Qian (1994) but also by sorting models like Rosen (1982) or the knowledge hierarchy model of Garicano and Rossi-Hansberg (2006).

However, these models do not consider dynamic reallocations within the hierarchy, as in incentive models (Lazear and Rosen, 1981; Lazear, 2004) and models of careers in organizations (i.e. Gibbons and Waldman, 1999a). Therefore, as a next step, we look at the relationship between the span of control and the probability of promotion to the next level in the hierarchy. We find that the number of subordinates in a layer is positively related to the probability of being promoted to the next layer. We also analyze the endogeneity of the span. We find that the number of subordinates in the previous layer has a positive effect on the number of subordinates in the current layer. These findings tend to indicate that firms learn about individuals' general and managerial ability by allocating them to positions where they have responsabilities.

The paper is structured as follows. Section 2 discusses the literature about hierarchies and the empirical implications of the different models. Section 3 provides a detailed description of the dataset, as well as some summary statistics. Section 4 introduces our empirical strategy and shows our results. Section 5 concludes.

2 Literature

2.1 Theory

Many theories have been developed that try to understand the economic problems that hierarchies are supposed to solve (for an early survey, see Holmstöm and Tirole, 1989, pp. 106-126). These theories can roughly be divided in five groups *for our purposes*: hierarchies as information processors, hierarchies as supervision technologies, hierarchies as incentive mechanisms, hierarchies as sorting and learning mechanisms, and knowledge based hier-

archies. We discuss each of them and what are their implications regarding the span of control and its relationship with careers and wages.

2.1.1 Hierarchies as information processors

In this literature, hierarchies are designed to process information optimally. The main paper that we consider is Bolton and Dewatripont (1994) (see also surveys by Radner, 1992 and Van Zandt, 1998). The aim of the organization is to minimize both the costs of processing information and the costs of communicating this information. Agents can specialize processing the same type of information but more specialization also implies more coordination and therefore higher costs of communication. This explains why efficient networks are centralized. They also find that efficient networks take a pyramidal forms, as individuals report only to one agent.

This theory is difficult to test with our data, since we have no information about the way information is processed. However, indirect implications can be tested. Among these, their model predicts that the span of control decreases along the hierarchy and that a reduction of communication costs leads to flatter organizations.

One criticism against this literature is the oversimplistic representation of the agent. The authors recognize this limitation:

> "The management literature stresses other dimensions besides work-overload and communication costs, such as motivation of managers, making lower level employees more responsible and eager to take initiatives, etc. A natural avenue for future research is to include some of these dimensions into our model and explore how they affect the design of internal organizations" (p.835)

We discuss some of these issues below.

2.1.2 Hierarchies as supervision technologies

Our reference paper is Qian (1994). His paper extends previous work on supervision by Williamson (1967) and Calvo and Wellisz (1979) and on efficiency wage theory by Shapiro and Stiglitz (1984). He develops a model of hierarchical production and efficiency wages with endogenous probability of detection. Supervision is used to mitigate moral hazard, and the probability of monitoring decreases with the span. However, there is also loss of control

along the hierarchy. The trade-off is the following: reducing the number of levels decreases cumulative loss but increases the span, and therefore leads to higher wages. The organization therefore tries to find the optimal number of layers and average span to maximize production.

His model generates interesting testable predictions:

> "First, in the optimal hierarchy in which all managers and workers are identical ex ante, wages fall and efforts decrease as one moves from the top to the bottom of the hierarchies. [...] Second, as the size of the hierarchy increases, both efforts and wages of managers at the top increase because their marginal product increases, and both effort and wages of workers fall because their marginal product declines." (p.528)

One limitation of this approach is that it is not clear to see the dynamics of careers.

2.1.3 Promotions in hierarchies as incentives mechanisms

Tournament theory provides another incentives theory but based on ex ante incentive mechanism provided by promotions. Individuals have incentives to perform well relative to thir peers to increase their probability of being promoted (Lazear and Rosen, 1981). Allowing for multi-periods tournaments, Rosen (1986) provides a model that generates an interesting testable prediction: optimally set wages (leading to effort being equal in all layers) increase along the hierarchy when individuals are risk averse.

Limitations of that type of analysis, that we discuss more in details in the next subsection, is that individuals are often considered to be identical. If they are not, then observable differences in ability affect negatively the incentives effect. However, if differences in ability are not observable, then the organization also learns about the agent's ability. This problem is considered by Lazear (2004). He generates a few testable implications. First, promotions are based on past performance. Second, effort diminishes drastically after the last promotion. Third, individuals in higher levels have higher expected ability.

2.1.4 Learning, assignment and selection in hierarchies

In assignment models, individuals of higher ability are assigned to positions where they are more productive at. In Rosen (1982)'s model, manager's

ability is spread along the hierarchy (decisions of managers matter for the productivity of production workers) and therefore receive higher wages. However, in practice, firms only learn progressively about managerial ability by observing individuals' performance and individuals are reassigned to new positions on the basis of their expected ability (see e.g. Gibbons and Katz, 1992; Farber and Gibbons, 1996).

Recently, Gibbons and Waldman (1999a) proposed to combine various building blocks models to better explain careers in organizations. They show that a model with job assignment, learning and on-the-job human capital accumulation generates many of the stylized facts about careers in organizations (Baker, Gibbs and Holmström, 1994). However, their model ignores externalities of managers' ability on workers' productivity, and incentive issues (see however Gibbons and Waldman, 1999b).

2.1.5 Knowledge based hierarchies

In this type of models, firms use hierarchies to organize knowledge optimally and to solve coordination problems in the presence of specialization. These models are unique in the sense that they look at the effect of information technologies on the shape of hierarchy, the span of control and, more recently, on the wage structure within firms. Their model generates a unique set of predictions.

In Garicano (2000), ex ante identical individuals decide to invest in acquiring knowledge to solve problems. The optimal organization of work has the following properties: workers are allocated to different layers according to the type of knowledge that they have learned (individuals at higher levels specialized in solving harder problems) with no overlapping of knowledge. Technological change affects organizational design. The model predicts the following. First, a decrease in both the cost of communication and the cost of acquiring knowledge increases the span of control. Second, these two different aspects have different implications on the number of layers: cheaper acquisition of knowledge reduces the number of layers, but cheaper transmission of knowledge has an ambiguous effect. Third, an increase in complexity reduces the span of control and increases the number of layers.

Building on Garicano (2000), Garicano and Rossi Hansberg (2006) provide an equilibrium theory where agents differ in cognitive ability (high ability agents have lower cost of acquiring knowledge) and wages are used to allocate workers to teams. Therefore, the initial assignement of workers to

layers has important efficiency implications. This theory provides a richer set of testable predictions. First, there is positive sorting: high ability managers hire high ability workers, allowing the manager to specialize in solving the hardest problems. Second, wages are increasing and convex in ability. Third, smarter agents work in higher layers and manage larger teams, i.e. there is segmentation by skill. Fourth, improvement in the access to information (lower learning costs) leads to more decentralization, higher span of control, an ambiguous effect on the number of layers and an increase in within and total wage inequality. Fifth, improvement in communication leads to higher wage inequality between layers, an increase in the span of control, and an increase in the number of layers.

They discuss how their model can explain the evolution of hierarchies observed over the 80's and 90's. At the end of the 80's and the beginning of the 90's, decrease in the cost of accessing information led to changes in the wage structure and the organization of production. Cheaper knowledge led to an increase in the span, an increase in the demand for skills, a decrease in the number of layers, and an increase of wage inequality within and across layers. In the mid and late 90's, a decrease in communication costs was associated with an increase in the span, an increase in wage inequality between layers (bot not within) and an ambiguous effect on the number of layers (stable then increasing).

Garicano and Hubbard (2004) extend the analysis to include on the job training. They find that on the job training reinforces positive sorting between workers and managers. More talented managers select workers who can solve more problems by themselves (and ask less questions) and that have a lower learning cost on the job.

Limitation of this type of analysis is that individuals are either identical ex ante (Garicano, 2000) or they differ according to their cognitive ability, which is known ex ante. Therefore, individuals are always allocated optimally and the model generates few implications about mobility within the hierarchy.

2.2 Empirical Evidence

Empirical evidence about these theories of hierarchy has been scarce and has mostly used survey data. Ortín-Ángel and Salas-Fumás (2002) use survey data from a repeated cross-section of 669 Spanish firms for the period 1990-1992. They find that wage differences between layers is lower than span of control at any position, and that manager's human capital explains a large

fraction of wage differences between layers, suggesting an allocation process of talent along the hierarchy.

Rajan and Wulf (2003) document the evolution of the shape of the hierarchy using survey data from a panel of more than 300 large U.S. companies over the period 1986-1999. They observe a flattening of the firm: more individuals report directly to the CEO, the span of control has increased and the number of layers has diminished. Moreover, the structure of pay has changed as well, organizations moving towards more pay inequality. They discuss potential explanations for their results, including technological change and change in product market competition.

Garicano and Hubbard (2004) use census data about U.S. law firms and test the theory of positive sorting. They find evidence in favor of their theory: partners and associates are sorted by law school quality but not by experience.

Finally, Fox (2006) uses the Swedish linked employer-employee dataset and provides some evidence consistent with the Garicano and Rossi-Hansberg (2006) model, as firm-size wage gaps increase with job responsability for managerial employees.

2.3 Our analysis

In this paper, we look at the link between wage, bonus, promotions and span of control, and at the reallocation process of talent within the hierarchy. We focus our attention on the dynamic process of control and job reallocation inside a given firm, as opposed to the previous studies.

The theoretical model that we test is the following: individuals accumulate general and managerial human capital on the job; firms learn about the general (possible task specific) and managerial ability of their employees, assign them to job levels and teams according to what is learned about their ability, as individuals are assigned to their most productive use; therefore, their span of control depends on their expected ability. Their ability moreover generates externalities on workers. Managers also supervise workers and firms provide incentives to their workers (through wage structure, promotions, bonuses and promises of higher future wages).

3 Data

The dataset provides confidential personnel records for all domestic[3] employees from a large European firm. To protect the anonimity of the firm, we can only disclose a few elements describing its activities. The firm operates in an high tech manufacturing industry, has grown significantly over the last decade, has been very innovative and has remained one of the world leaders in its product line. The frequency of observations is monthly and spans the period from January 1997 to May 2004. The dataset was actually provided in two waves: January 1997-July 2001, and September 2001-May 2004. The second wave provides data after the company switched to another Enterprise Resource Planning (ERP) process. As such, it can be seen as a major technological change facilitating communication and the circulation of information within the firm.

Figure 1 shows the evolution of the size of the company (we only consider the mother company and not the smallest subsidiaries). Over the 8-years period spanned by our dataset, the company has almost doubled the number of employees.

<Insert Figure 1>

3.1 Job levels

The distribution of formal authority in the firm is relatively simple. There are only 5 job levels based on job description: non managerial employees (job level 0), lower management (job level 1), middle management (job level 2), upper management (job level 3) and top management (job level 4).

Moreover, the company also uses a dual career ladder: for the first two positions, they have professional managers (job level 1b) and professional middle managers (job level 2b). The reason for making this distinction is that the company wants to offer career opportunities for individuals with technical skills, but who might not be suited for managerial positions. As a consequence, they rarely supervise teams of workers, but promotion to these job titles provides important wage increases, and therefore ex ante motivation.

[3]Although the percentage is declining, a large bulk of the firm's activities still take place within the country.

Finally, the firm decided to add a new **informal** layer in 2001. The role of the individuals at this level were to help the manager fulfilling her supervisory tasks and facilitate a more intensive production process. We refer to individuals at this level as assistant managers (job level 0.5). The observation that the number of job levels has not increased formally, despite the dramatic growth of the firm, can be seen as very similar to the finding in Baker, Gibbs and Holmström (1994) (henceforth BGH).

Figure 2 describes the job levels in the firm.

<Insert Figure 2>

The number of managers has increased, but proportionaly less than employment (Figure 3), implying an increase in the span of control (see more on this below).

<Insert Figure 3>

In September 2001, the company tried to remedy to that evolution and hired a significant amount of new managers. Moreover, as we just mentionned, the firm has introduced this new informal layer of assistant manager. These assistant managers have been allocated in those departments where managers had the highest span of control.

Evidence suggests therefore that the organization has become more decentralized and has introduced a new layer.

3.2 Job Transition

Figures 4 shows the number of promotions along the hierarchical career for the two periods. During the first period, there were about two promotions a month from worker to manager; three promotions a month from worker to professional manager. While the average number of promotions remained relatively stable for managers in the second period, it increased dramatically for professional managers to an average of 4.5 promotions a month. Another striking observation is that professional managers are much less likely to be promoted further along the hierarchy. On the contrary, the average number of managers being promoted to middle managers increased slightly from 0.4 to 0.6. Promotions to upper management is much rarer and only concerns middle managers. Finally, we observed one promotion to top management. Demotions are rare and are omitted from the figure. We also notice entry and

exit at all layers of the firm, although limited at the last two layers, *providing further evidence against the importance of "ports of entry and exit".*

<Insert Figure 4>

3.3 Teams, departments, and span of control

An unusually rare feature of this dataset is that relationships within the hierarchy are reported, i.e. for each employee, it is known precisely who is his manager, to whom the manager reports, and so on. This means that we have a clear description of the chain of command. On the basis of this information, we created our unit of analysis, a team, or a "cell"[4], defined as a group of workers with the same supervisor and the same chain of command. This is the smallest unit in the chain of command. This clearly established relationship allows a richer analysis of the internal economics of the firm than previous studies.

Teams often coincide with the department, especially the smaller ones, while the large ones sometimes include more than one department. Some managers are in some cases in charge of more than one department (for example, one administrative department and two production departments with closely realted activities). The number of teams in our dataset has increased from 235 in May 2000 to 382 in May 2004, while the number of departments increased from 342 by name (344 by number) in January 1997 to 437 by name (420 by number) in July 2001, and then to 607 by name (415 by number, 800 including subdepartments) in May 2004.

Departments are organized in five larger units, dividing financial, sales and marketing, R&D, administrative and production tasks.

The span of control is then simply constructed by combining information about job levels and the chain of command. We define the **span of control** of a manager as the number of subordinates who refer to him as the manager. It is also equal to the size of the team. Table 3 shows the evolution of the span of control for managers.

[4]Looking at the evolution, we can study the **internal biology of the firm** (see Smeets and Warzynski, 2006a). By definition, our notion of the cell is intrinsically linked to the individual in charge of the cell. When the manager of the cell leaves her position (either because she is promoted, she is reallocated to another cell or she leaves the firm), the position becomes vacant. The cell dies and is replaced by another one, with a new individual in charge. Moreover, units are sometimes reorganized, leading to a process of creative destruction of cells.

<Insert Table 1>

We see that the manager's span of control has increased on average, as was already seen on Figure 2. After a temporary decline after 2001, the span started rising again.

The notion of the span of control becomes more complicated for middle managers. Middle managers are responsible for managers but also have their own team, which is not responsible for workers. Moreover, middle managers also command indirectly workers under a manager. Therefore, we define three different measures of the span: the direct span (number of managers), the team and the indirect span (number of workers reporting through the manager). In our regressions, we use only the indirect span, in line with the theoreticl idea that talent is spread through the hierarchy. Table 4 provides summary statistics about the evolution of these measures.

<Insert Table 2>

The team managed by midde managers has remained relatively constant over the period, while the average number of managers has slightly increased.

For higher levels of management, the number of dimensions to be considered increases even more. For a matter of concision, we omit to discuss them in this paper.

3.4 Individual information

Besides information about job description, position in the chain of command, department and unit, we have information about wage, bonus, tenure in the firm, age, gender, nationality,...

Wage is the monthly wage before tax. Bonus is the monthly bonus before tax. Bonuses are usually concentrated around the end of the year, but also occur during the year. Tenure is defined in years and is defined as the difference between the observation data and the hiring date. Age is defined in years. We have detailed information about the individual education level. We use a summary measure (EDU) where individuals are divided in five groups: those with basic education (EDU=0), those with some technical degree or vocational education (EDU=1), those with technical higher education (EDU=2), those with BA or BSc level education (EDU=3) and those with a Ms, MA or PhD level education (EDU=4).

4 Empirical Analysis

4.1 Evolution of the wage gap between levels

We first look at the evolution of wage inequality between job levels. To analyze this, we run a traditional Mincerian regression of monthly wage over human capital variables (firm tenure and age in a quadratic form) and job level variables for each month in the dataset. We also include education dummies and gender as control variables. The coefficients for each job level measure the wage difference between a worker (job 0, our control group) and the individuals in various managerial positions. We then plot the coefficients of the job levels on Figure 6 to illustrate the evolution of wage differences between layers in our firm.

$$\begin{aligned}\log W_{it} &= \alpha_0 + \alpha_1 TENURE_{it} + \alpha_2 \left(TENURE\right)_{it}^2 + \alpha_3 AGE + \alpha_4 \left(AGE\right)_{it}^2 \\ &\quad + \sum_{JL} \alpha_{JL} \left(D_{JL}\right)_{it} + controls + \varepsilon_{it} \quad \forall t\end{aligned}$$

<Insert Figure 5>

We see that wage inequality has increased between levels, and also that the difference between traditional managers and professional managers has increased as well. We suspect that part of this difference might be explained by the fact tht professional managers do not exert supervision tasks. We test this in the following subsections.

4.2 Span of Control, Wages and Bonuses

We then test the effect of the span of control on wage. Our assumption is that more responsability should be associated with higher wage, either because individuals have been selected to become manager and have higher ability, or because they exert more effort.

$$\begin{aligned}\log W_{it} &= \alpha_0 + \alpha_1 TENURE_{it} + \alpha_2 \left(TENURE\right)_{it}^2 + \alpha_3 AGE + \alpha_4 \left(AGE\right)_{it}^2 \\ &\quad + \sum_{JL} \alpha_{JL} \left(D_{JL}\right)_{it} + \alpha_{S,M} D_M SpanMan_{it} + \alpha_{S,MM} D_{MM} SpanMidMan_{it} \\ &\quad + controls + \varepsilon_{it}\end{aligned}$$

<Insert Table 3>

Results are shown in table 5. Age and tenure have the usual effect. However, age appears to have a stronger effect on compensation than tenure. Especially once controlling for job level, tenure has a remarkably small effect, a finding similar to BGH (table 5, p. 907).

The effect of job levels provide an average of figure 5. However, the wage difference between layers is slightly lower when we control for the span. As such, it does not bring additional explanatory power but instead divides the job level effects in two components: one linked to the size of the team and another purely linked to the level. For ease of interpretation, we use a rescaled measure of the span, dividing the number of individuals supervised by the manager/middle manager by the average span of managers/middle managers over the period. The span of control has a positive effect on compensation for both managers and middle managers, in line with several of the theories we discussed in section 2. The effect is relatively large: For managers, supervising a team twice as large as the average implies a salary difference of 2.8%. For middle managers, being indirectly responsible for twice as many workers implies a wage difference of 4.1%. This shows that the firm rewards supervision tasks with higher salaries and uses wage differentation within job level. Looking at the second period, we see that wages of managers and middle managers have become slightly less sensitive to the span but more sensitive to the level.

We also ran a similar regression by job level to investigate further this wage heterogeneity within job level. For managers, we simply use the number of workers they supervise divided by the average span of managers over the period as an adjusted measure of the span:

$$\begin{aligned} \log W_{it} &= \alpha_0 + \alpha_1 TENURE_{it} + \alpha_2 \left(TENURE\right)_{it}^2 + \alpha_3 AGE + \alpha_4 \left(AGE\right)_{it}^2 \\ &\quad + \alpha_{S,M} D_M AdjSpanMan_{it} + controls + \varepsilon_{it} \end{aligned}$$

<Insert Table 4>

For middle managers (job level 2), we use the indirect measure of the span, i.e. the number of workers supervised by managers themselves supervised by the middle manager, divided by the average indirect span of middle managers

over the period:

$$\begin{aligned}\log W_{it} &= \alpha_0 + \alpha_1 TENURE_{it} + \alpha_2 (TENURE)^2_{it} + \alpha_3 AGE + \alpha_4 (AGE)^2_{it} \\ &\quad + \alpha_{MM} AdjSpanMidMan_{it} + controls + \varepsilon_{it}\end{aligned}$$

<Insert Table 5>

Similar results are found, meaning that within job level, supervising more workers translates into higher wages.

We run a similar regression using bonuses instead of wages. Wages are very likely to be less flexible than bonuses, so that firms might use bonuses instead of wages to reward supervision. We therefore test the idea that, when individuals receive bonuses, the size depends on responsability. We do not test occurence of bonus as a function of performance since the latter is unavailable in our dataset.

$$\begin{aligned}\log BONUS &= \alpha_0 + \alpha_1 TENURE_{it} + \alpha_2 (TENURE)^2_{it} + \alpha_3 AGE + \alpha_4 (AGE)^2_{it} \\ &\quad + \sum_{JL} \alpha_{JL} (D_{JL})_{it} + \alpha_{S,M} D_M SpanMan_{it} + \alpha_{S,MM} D_{MM} SpanMidMan_{it} \\ &\quad + controls + \varepsilon_{it}\end{aligned}$$

Results are shown in table 6. We find that bonuses are much more sensitive to job levels than wages. Looking at the effect of the span, we obtain similar results (see table 6) than for the wage regression in the first period, but the span as manager has a negative effect in the second period. One explanation might be that the firm has used a different notion of the job, now defined more precisely. Other explanation is of course that the determination of bonuses has been changed dramatically, for example following negotiation with unions, leading to a lack of flexibility in a context of rising span of control. Yet another explanation is that the introduction of assistant managers has modified the logic of the determination. The size of the bonus is positively related to the number of subordinates as middle manager. Bonuses have also become more sensitive to rank, less to seniority and more to age.

<Insert Table 6>

To sum up, our results so far indicate:

- a positive link between span of control and wage

- an increase in the span of control

- the introduction of a new informal layer

- an increase in the wage gap between layers (independently of the span of control effect)

- promotions along the hierarchical ladder

The first result in particular can be explained by the knowledge hierarchy model, the assignment model and by the incentives model, and it would be difficult to disentangle these two effects. Moreover, it could be an artifact of the data, as most firms use **formal salary systems** that link responsabilities to wage level categories. We therefore decide to devote more attention to the issue of reallocation across job levels along the hierarchy.

4.3 Probability of promotion

As a next step, we analyze the relationship between the span of control and the probability of promotion. We perform a probit regression where the dependent variable is a dummy variable equal to 1 if the individual is promoted and 0 otherwise. We first consider the promotion probability from manager to middle manager, and relate it to the span as manager (in $t-1$). What we want to test is whether individuals who had more responsabilities in the previous layer have a higher probability of promotion. The idea is that the firm learned about the manager's ability to supervise workers and took the promotion decision accordingly. We also include age and age squared to control for the accumulation of (general) human capital variables. We also used seniority to control for the accumulation of firm specific human capital, but the variables were not significant. The variables used as controls include gender, education dummies (additional general human capital variables), and large unit dummies.

$$\begin{aligned} PROM^*_{it} &= \beta_0 + \beta_1 TENURE_{it} + \beta_2 (TENURE)^2_{it} + \beta_3 AGE + \beta_4 (AGE)^2_{it} \\ &\quad + \beta_{S,M} D_M SpanMan_{i(t-1)} + controls + \varepsilon_{it} \end{aligned}$$

where

$$PROM_{it} = \begin{array}{l} 1 \text{ if } PROM^*_{it} > 0 \\ 0 \text{ if } PROM^*_{it} \leq 0 \end{array}$$

<Insert Table 7>

Table 7 presents marginal changes. Since we use monthly data, promotions occur rarely in percentage. One has to compare our coefficient to the observed probability of promotion. We find that the lagged adjusted span as manager has a significant and positive effect on the probability to be promoted middle manager.

4.4 Endogeneity of span

In this section, we try to better understand the factors that influence the number of subordinates.

We first look at the relationship between the adjusted span as middle manager and the span as manager before promotion. In this regression, we therefore only use information from those individuals who were promoted from manager to middle manager during the period of analysis.

$$\begin{aligned} AdjSpanMidMan &= \gamma + \gamma_1 TENURE_{it} + \gamma_2 (TENURE)^2_{it} + \gamma_3 AGE + \gamma_4 (AGE)^2_{it} \\ &\quad + \gamma_{S,M} D_M AdjSpanMan_{i(t-1)} + controls + \varepsilon_{it} \end{aligned}$$

<Insert Table 8>

Our results confirm the hypothesis that high span as a manager has a positive effect on the span as middle manager. In other words, managing a large number of workers in the previous layer can be seen as a positive signal regarding your managerial ability, as firms learn gradually about individuals' managerial talent.

To sum up, our results illustrate that human capital and learning affect the number of subordinates, and that the number of subordinates also has implications for wages, bonus and career dynamics.

5 Conclusion

Our results appear to confirm implications from the Garicano and Rossi-Hansberg (2005) model and other models like Bolton and Dewatripont (1994), Rosen (1982) and Qian (1994). We find that the span of control has increased,

wage inequality has increased between layers. We also find that higher spans are associated with higher wages and -in most cases- higher bonuses.

But we also stress a different mechanism present in Gibbons and Waldman (1999): learning about managerial ability. Indeed, we find that the span can partly be determined by fast track decision from the firm, and that the span has implications for the future individual career. It partly explains promotion decisions, what suggests that firms "learn through the span", i.e. use the span decision as a way to learn about managerial ability.

Combining these two characteristics within a single theoretical framework opens new and exciting avenues for the study of careers in hierarchies, and explains our empirical results.

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Table 1: Span as manager (in May of each year)

	1997	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Mean	24.43	25.09	28.63	29.86	32.62	29.01	29.25	29.98
Median	16	17	17	17	20	16	16	16
Std. dev.	28.47	27.04	32.28	32.52	37.42	37.04	38.59	38.33
Min	1	1	1	1	1	1	1	1
Max	214	164	171	187	211	259	272	286
Nr. of obs.	159	172	148	161	177	214	231	254

Table 2: Direct and indirect span as middle manager (in May of each year)

Direct subordinates - Team

	1997	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Mean	22.30	17.37	26.77	24.79	24.65	13.59	13.70	21.14
Median	13	10	18	11	10	8	7	6
Std. dev.	22.68	22.78	29.38	34.22	39.48	19.57	26.01	53.47
Min	0	0	1	0	0	2	1	1
Max	214	164	171	187	211	259	272	286
Nr. of obs.	56	60	43	48	57	71	71	76

Direct subordinates - Managers

	1997	1998	1999	2000	2001	2002	2003	2004
Mean	2.79	2.90	3.42	3.04	3.09	3.10	3.52	3.39
Median	2	2	3	2	2	2	3	3
Std. dev.	3.56	3.58	3.74	3.51	3.96	3.27	3.57	3.73
Min	0	0	0	0	0	0	0	0
Max	18	17	12	13	17	13	13	20
Nr. of obs.	56	60	43	48	57	71	71	76

Indirect subordinates - Workers

	1997	1998	1999	2000	2001	2002	2003	2004
Mean	90.33	88.52	125.05	119.71	127.63	106.42	109.54	118.85
Median	37	36	57	39	40	42	41	45
Std. dev.	125.35	126.09	163.16	170.73	195.42	167.55	177.11	180.78
Min	1	1	1	1	1	1	1	1
Max	615	640	784	691	871	821	875	975
Nr. of obs.	56	60	43	48	57	71	71	76

Table 3A: Wage regression (first period)

	Jan 1997 - July. 2001		
Dependent variable: $\log W$			
Tenure	0.011*** (0.0001)	0.005*** (0.0001)	0.005*** (0.0001)
Tenure^2 /100	-0.017*** (0.0005)	-0.005*** (0.0004)	0.003*** (0.0005)
Age	0.038*** (0.0003)	0.037*** (0.0003)	0.037*** (0.0003)
Age^2 / 100	-0.041*** (0.0004)	-0.041*** (0.0004)	-0.041*** (0.0004)
Technical or vocational education	0.039*** (0.001)	0.043*** (0.001)	0.043*** (0.001)
Technical higher education	0.059*** (0.001)	0.056*** (0.001)	0.055*** (0.001)
BA, BS	0.25*** (0.001)	0.21*** (0.001)	0.21*** (0.001)
MA, MSc, PhD	0.45*** (0.001)	0.34*** (0.001)	0.34*** (0.001)
Female	YES		
Job level: Assistant Manager	-	-	-
Job level: Prof. Manager	-	0.27*** (0.002)	0.27*** (0.002)
Job level: Manager	-	0.32*** (0.002)	0.30*** (0.002)
Job level: Prof. Mid. Manager	-	0.46*** (0.003)	0.46*** (0.003)
Job level: Mid. Manager	-	0.56*** (0.002)	0.53*** (0.002)
Span as Manager / 27.86	-	-	0.028*** (0.001)
Span as Middle Manager / 107.3	-	-	0.041*** (0.002)
Month dummies	YES		
Adj. R^2	0.61	0.73	0.73
Nr. Obs.	256,707		

Table 3B: Wage regression (second period)

	Sept. 2001 - May 2004		
Dependent variable: $\log W$			
Tenure	0.011*** (0.0001)	0.005*** (0.0001)	0.005*** (0.0001)
Tenure^2 /100	-0.017*** (0.0004)	-0.003*** (0.0003)	-0.003*** (0.0003)
Age	0.031*** (0.0003)	0.029*** (0.0002)	0.029*** (0.0002)
Age^2 / 100	-0.033*** (0.0003)	-0.031*** (0.0003)	-0.031*** (0.0003)
Technical or vocational education	0.051*** (0.001)	0.052*** (0.001)	0.052*** (0.001)
Technical higher education	0.10*** (0.001)	0.093*** (0.001)	0.092*** (0.001)
BA, BS	0.34*** (0.001)	0.284*** (0.001)	0.282*** (0.001)
MA, MSc, PhD	0.52*** (0.001)	0.393*** (0.001)	0.393*** (0.001)
Female	YES		
Job level: Assistant Manager	-	0.21*** (0.002)	0.21*** (0.002)
Job level: Prof. Manager	-	0.29*** (0.001)	0.29*** (0.001)
Job level: Manager	-	0.36*** (0.001)	0.35*** (0.001)
Job level: Prof. Mid. Manager	-	0.47*** (0.003)	0.47*** (0.003)
Job level: Mid. Manager	-	0.59*** (0.003)	0.56*** (0.003)
Span as Manager / 29.47	-	-	0.019*** (0.001)
Span as Middle Manager / 110.45	-	-	0.032*** (0.001)
Month dummies	YES		
Adj. R^2	0.68	0.81	0.81
Nr. Obs.	241,949		

Table 4: The relationship between wages and span. for managers only

	Jan. 1997 - July 2001	Sept. 2001 - May 2004
Dependent variable: $\log W$		
Tenure	0.008*** (0.0005)	0.002*** (0.0005)
Tenure^2	-0.031***(0.002)	-0.010***(0.002)
Age	0.023*** (0.001)	0.021*** (0.001)
Age^2	-0.025*** (0.002)	-0.022*** (0.002)
Adjusted Span as Manager	0.014*** (0.001)	0.013*** (0.001)
Education dummies	YES	
Female	YES	
Month dummies	YES	
Adj. R^2	0.58	0.33
Nr. Obs.	9005	7766

Table 5: The relationship between wages and span. for middle managers only

	Jan. 1997 - July 2001	Sept. 2001 - May 2004
Dependent variable: $\log W$		
Tenure	0.014*** (0.001)	0.006*** (0.001)
Tenure^2	-0.028*** (0.003)	-0.009*** (0.003)
Age	-0.026*** (0.004)	0.001 (0.004)
Age^2	0.029***(0.004)	-0.002 (0.004)
Span as Middle Manager	0.053*** (0.002)	0.035*** (0.002)
Education dummies	YES	
Female	YES	
Month dummies	YES	
Adj. R^2	0.39	0.24
Nr. Obs.	3856	3384

Table 6: Bonus regressions

	Jan 1997 - July. 2001	Sept. 2001 - May 2004
Dependent variable: $\log Bonus$		
Tenure	0.005** (0.002)	-0.0003 (0.002)
Tenure^2 /100	-0.020*** (0.008)	0.006 (0.007)
Age	0.014** (0.006)	0.023*** (0.005)
Age^2 / 100	-0.018*** (0.007)	-0.030*** (0.006)
Education dummies	YES	
Female	YES	
Job level: Assistant Manager	-	0.31*** (0.031)
Job level: Prof. Manager	0.39*** (0.021)	0.56*** (0.021)
Job level: Manager	0.58*** (0.024)	0.76*** (0.024)
Job level: Prof. Mid. Manager	0.73*** (0.041)	0.84*** (0.046)
Job level: Mid. Manager	0.86*** (0.029)	1.13*** (0.034)
Adjusted Span	0.042*** (0.016)	-0.050*** (0.012)
Adjusted Span	0.056*** (0.018)	0.19*** (0.021)
Month dummies	YES	
Adj. R^2	0.59	0.48
Nr. Obs.	9646	12910

Table 7: Determinants of promotion to middle manager (marginal changes)

Dependent variable:	$PROM_{Man-MidMan}$
Tenure	0.0001 (0.0002)
Tenure^2/100	-0.0005 (0.0008)
Age	0.0014**(0.0005)
Age^2/100	-0.0018** (0.0006)
Lagged adjusted span as manager	0.0007*** (0.0002)
Education Dummies	YES
Female	YES
Monthly dummies	YES
Pseudo-R^2	0.06
Nr. obs.	16572
Log likelihood	-265.13
Obs. probability	0.0024
Predicted probability	0.0013

Table 8: Determinants of the number of subordinates as middle manager

Dep. var.: Adjusted (indirect) span as middle manager	
Adjusted span as manager before promotion	0.29*** (0.05)
Age	1.30*** (0.19)
$Age^2/100$	-1.58*** (0.21)
Seniority	-0.13*** (0.05)
$Seniority^2/100$	0.59*** (0.16)
Gender	YES
Unit dummies	YES
Education dummies	YES
Constant	YES
Adj. R^2	0.28
Nr. Obs:	1492

Figure 1: Evolution of the Size of the Firm

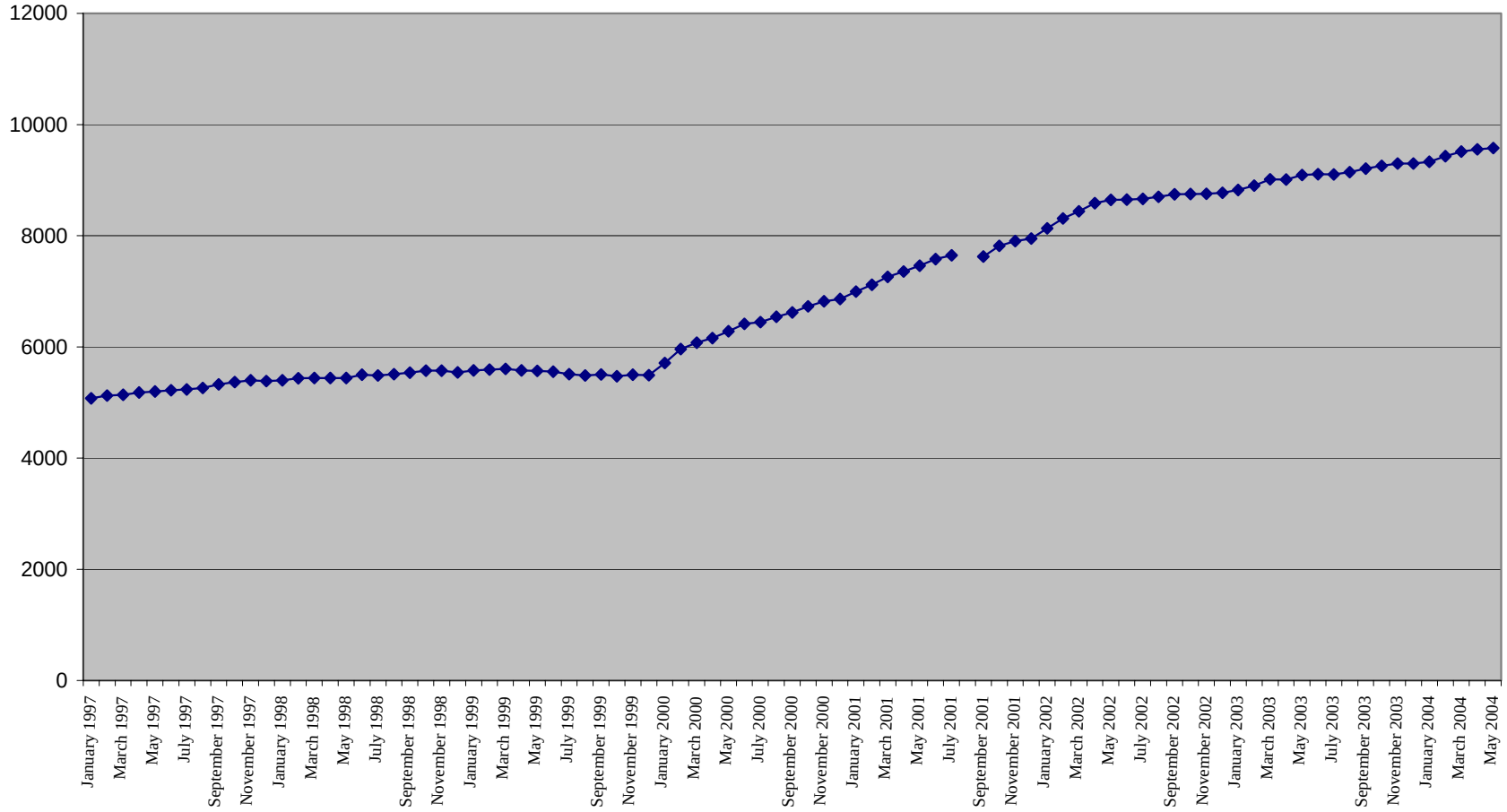

Figure 2 **Type of Promotions**

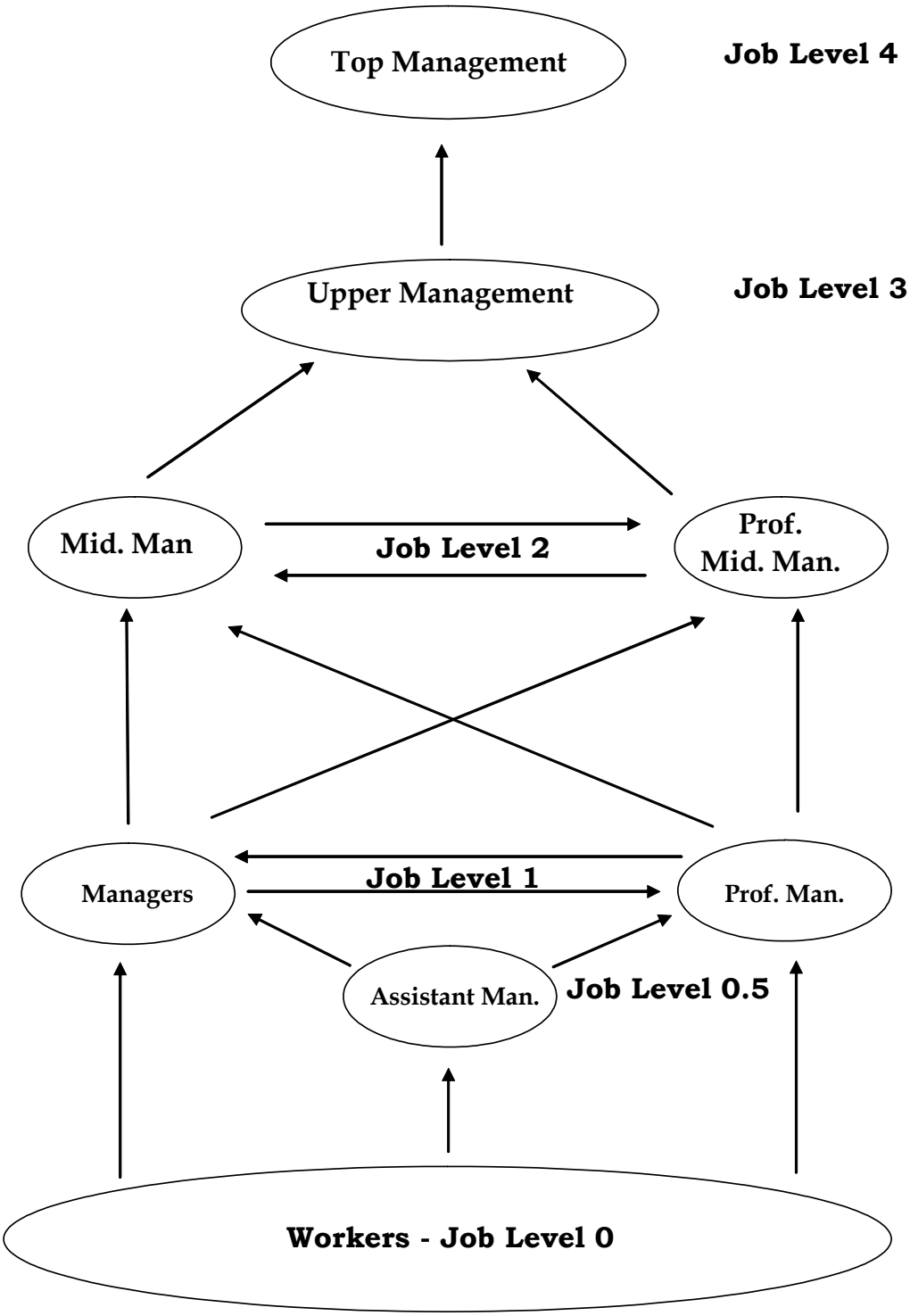

Figure 3: Evolution of the index of employment, lower managerial employment and middle managerial employment

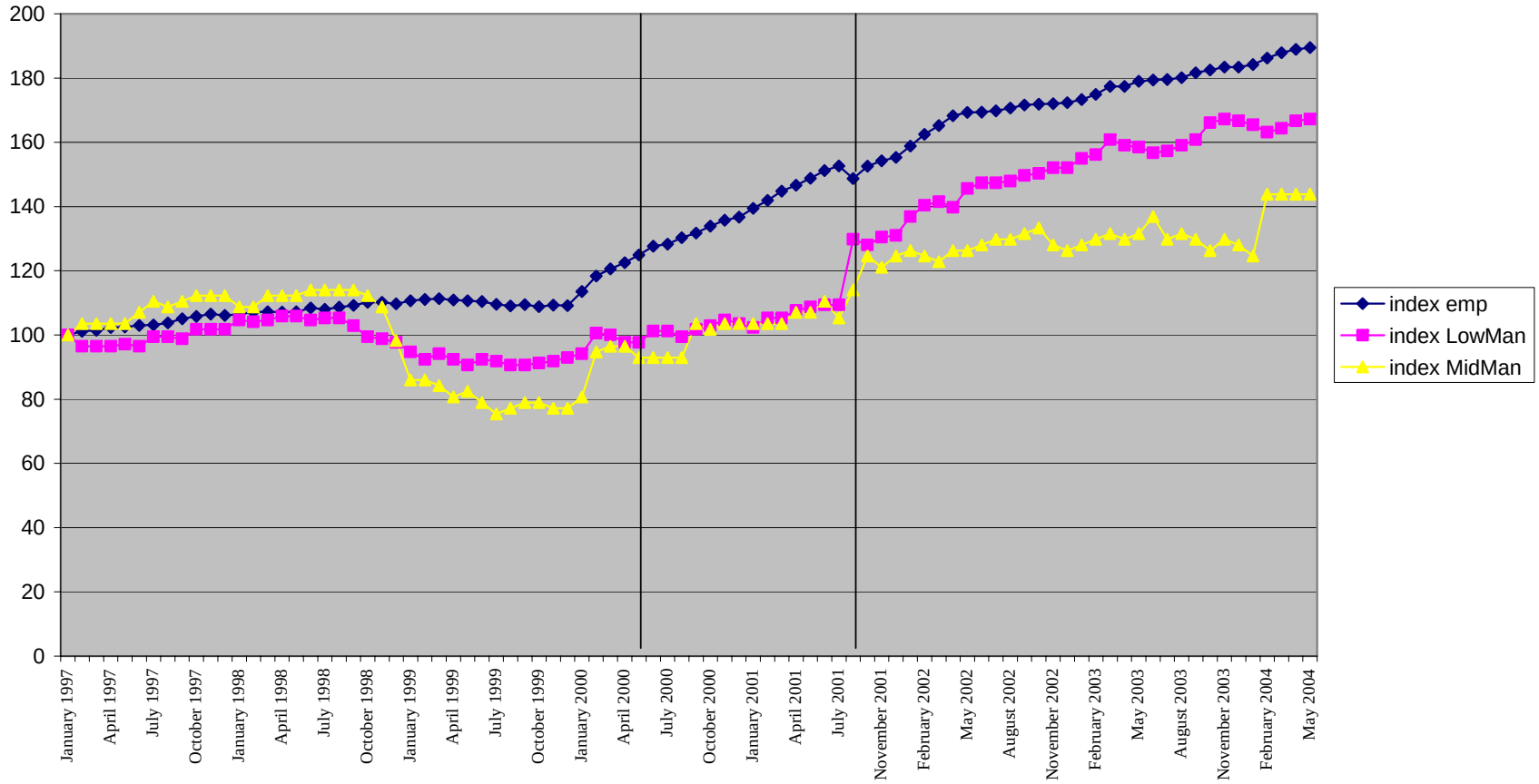

Figure 4a

Number of Promotions and Outside Hires by Type: January 1997 - July 2001

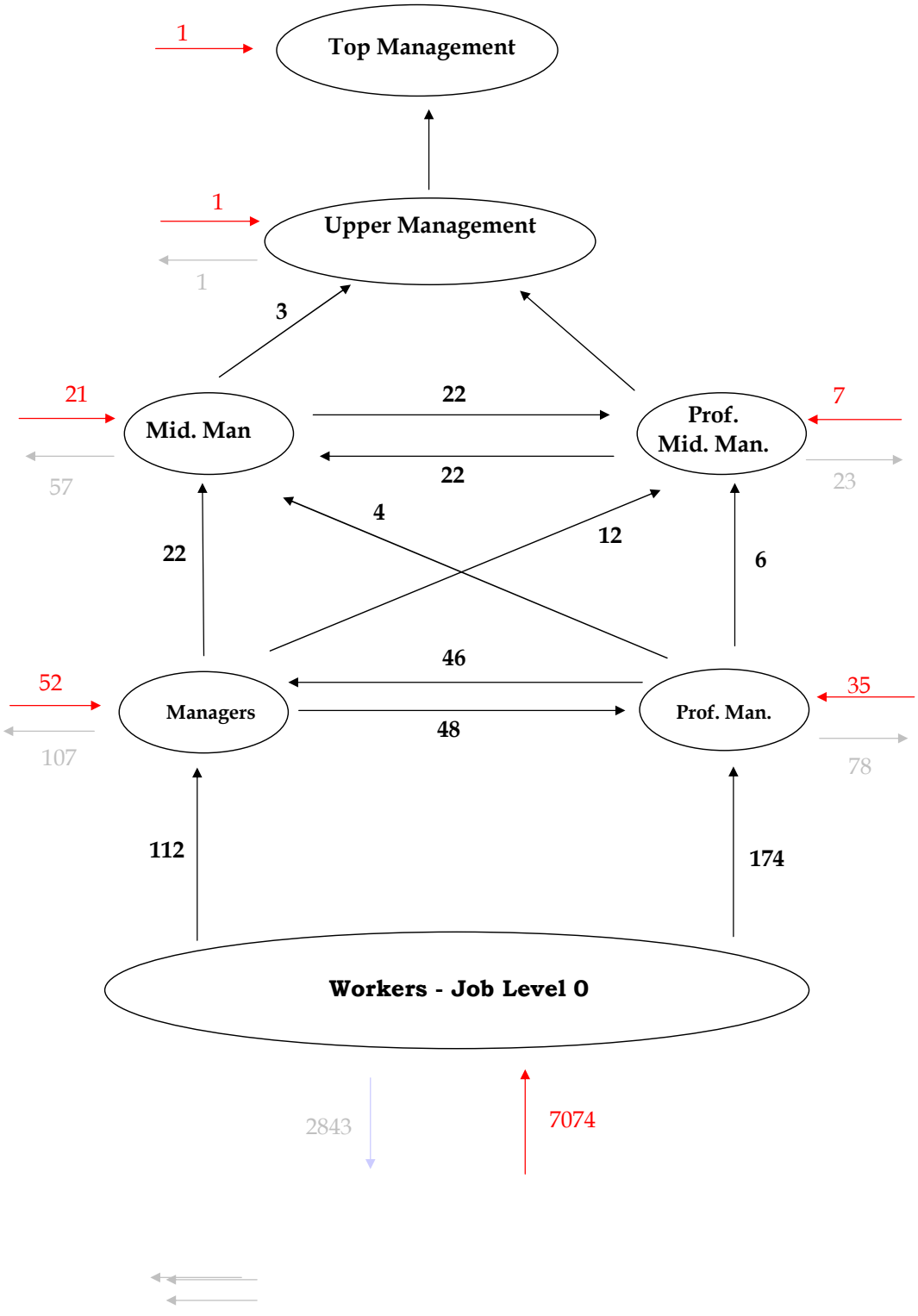

Figure 4b

Number of Promotions and Outside Hires by Type: September 2001 - May 2004

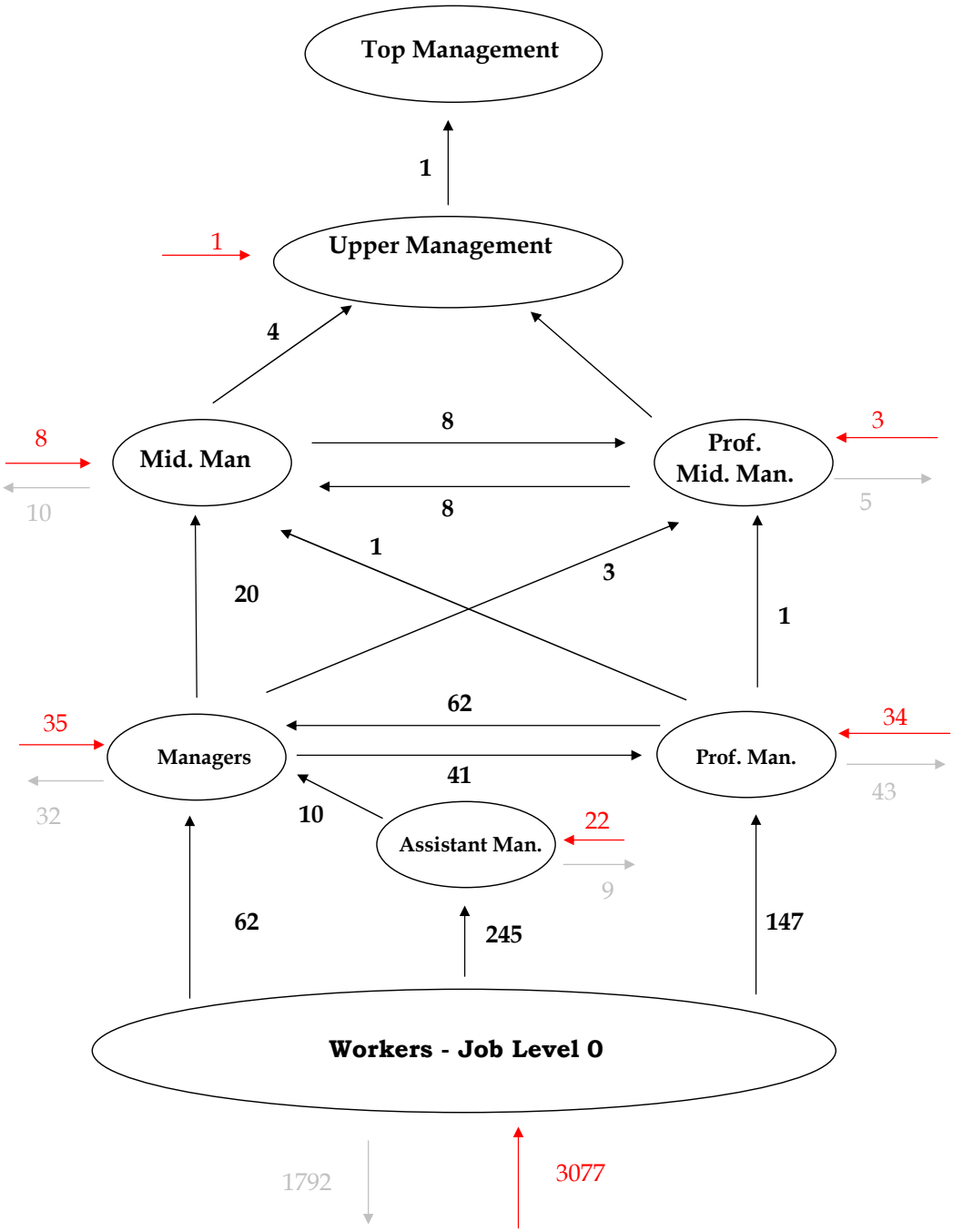

Figure 5: Evolution of the wage gap between job levels